Introduction to Digital Technologies for COT

US WEST COMMUNICATIONS

Introduction to the Course

January, 2000

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0.01	Revised original course material and updated test questions	01/11/00	Mod 0 Intro.doc

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Table of Contents

Introduction 1
Course Goal 1
Benefits 1
Modules 1
Outline 2
Purpose/ Preview 3
Objective 3
Testing 3
Pass/Fail 4
Role of Instructor 4
Course Material 4
Indexes 4
Self-instruction 5

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INTRODUCTION

Welcome to "Introduction to Digital Technologies for COT." We're glad you're here.

Course Goal

The goal of this course is to provide you with a broad foundation of telecommunications skills and knowledge to prepare you for later, more advanced training.

Benefits

This course will enable you to:

- ✓ Understand the "big picture" of the network.
- ✓ Prepare for your future by learning the "language" of digital communications.
- ✓ Appreciate the importance of new technologies, such as Signaling System 7 and ISDN.
- ✓ Enhance and enrich your knowledge with helpful, relevant information that will stay with you wherever your job path takes you.
- ✓ Discover a variety of subjects, such as carrier systems, CLASS features and Common Channel Signaling.
- ✓ Learn through a variety of media – print, video and lecture.

Modules

The course is divided into 7 different modules. Within each module there may be different components. The course outline is as follows:

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Outline

Module 1: Understanding Digital Concepts and Components

- Book I 4 hours
- Book II 3.5 hours
- Book III 3.5 hours 30/35

Module 2: Converting Numbering Systems

- Decimal to Binary, Octal, Hexadecimal and back 4.5 hours

video Module 3: Electrostatic Discharge Prevention 100%

- Electrostatic Discharge video tape viewing to begin the module 1 hr.

Module 4: Call Processing 6 hours

Module 5: Network Monitoring & Analysis (NMA) 2 hours

Module 6: AMA Billing & Network Management 3 hours

Module 7: CCS/SS7 Signaling

- Book I 6 hours
  - SS7 Overview video tape viewing to conclude module at page 99
- Book II 2 hours
  - CCS/SS7 Custom Local Area Signal Services "CLASS Features" video tape viewing to conclude module at page 73

Format

The various modules of this course are segmented into parts, lessons, lesson components with instructor interaction and selectively supported by video tape viewing.

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Purpose/ Preview

At the beginning of each module you will find a Purpose and Preview page. The Purpose will give you a brief summary of what the module is all about and will explain why knowledge of the subjects is important to you. The Preview will list the subjects that are contained in the module.

Objective

Each module will contain a specific objective which will explain what is expected of you. Read the objective carefully.

Testing

At the conclusion of each module or lesson there will be a test. The objective will state the criteria for satisfactory performance on the test. You may not go on to the next module until you have met the test criteria listed in the objective. The criteria will also be listed on the test itself. You will not be able to refer to your lesson material during the test, except when specifically directed to do so. When directed to do so, you may use module Job Aids during the test.

You may not refer to any personal notes during the test. Lesson books, laptop computers, calculators and personal notes are to be turned over to the instructor before taking the test.

Copying or transcribing test questions is not permitted.

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Pass/Fail

This is a pass/fail course. This means that the student must meet the criteria listed in each objective or lesson in order to be considered "passing." The student must meet each objective in order to progress through the course, and to graduate. If the objectives are not met, the training will be terminated and the employee will return to the location specified by their immediate supervisor.

Role of Instructor

The instructor's role is to provide assistance to you whenever you need it. For example, you may have questions on the material or module subject concepts. Whenever you need to, ask your instructor for help. You are not judged on how frequently, or infrequently, you ask for help.

Course Material

As you move through the material, you will find plenty of review questions. On the page following the review, you will find the answers to the questions. It is in your best interest to do the review without looking at the answers. The reviews will reinforce the learning points. The reviews will also help you identify areas that may need extra attention. If you miss a review question, be sure to go back over the material to understand why you missed it.

Indexes

Subject indexes are found in the back of each module.

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Self-instruction

This course is self-instructional. This means that you, the adult learner, are responsible for your own learning. We will provide you with the tools to learn, but in the end, success will be up to you. Make the most of the course material.

Following are some tips on reading self-instructional material:

- ✓ Take frequent stretch breaks.
- ✓ Take notes as you move through the material. You may write in your books.
- ✓ Concentrate on your material, not others around you.
- ✓ Make sure you are comfortable and that you have adequate light for reading.

You may now start the course with Module I, Book I.

Welcome!

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Introduction to Digital Technologies for COT

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Module 1, Book I
Understanding Digital Concepts And Components

January, 2000

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0.01	Revised original course material and updated test questions	01/11/00	M1 BI intro.doc M1 BI pt A M1 BI pt B

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Table of Contents

INTRODUCTION 1
Module Format 1
OBJECTIVE - BOOK I 2
Testing 2
Passing 2

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INTRODUCTION

Module Format

The course's first module, titled *Understanding Digital Concepts and Components*, is broken into 6 parts, as follows:

Part A:	Analog and Digital Signals
Part B:	Carrier Systems
Part C:	Cross-connect Systems
Part D:	Pair Gain Systems; Universal Digital Channel
Part E:	Fiber Optics
Part F:	ISDN

For purposes of testing, we have divided Module 1 into three books.

Book I, the one you are reading now, contains Parts A, and B. You will take a test on this material before moving on to Book II.

Book II, contains Parts C and D.

Book III contains Parts E and F.

Each Part will list its purpose and the subjects to be covered.

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OBJECTIVE - BOOK I

At the conclusion of Module 1, Book I, the student will be able to correctly:

- ✔ Identify the characteristics, concepts and terms of analog and digital signals.
- ✔ Identify carrier system fundamentals, components and processes.

Testing

The student will be provided with a written test, comprised of multiple choice and matching term to definition type questions. During the test, the student may not refer to any reference material.

Passing

Evidence of satisfactory learning will be demonstrated by correctly completing 26 out of 34 questions on the test.

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Table of Contents

PART A: ANALOG AND DIGITAL SIGNALS 1
PURPOSE AND PREVIEW 1
Purpose 1
Preview 1
TELEPHONE TRANSMISSION 3
Two Systems 3
Beginning 3
THE ANALOG SIGNAL 5
Overview 5
REVIEW 7
CHARACTERISTICS OF ANALOG SIGNALS 11
Characteristics 11
AMPLITUDE 13
Overview 13
Example 13
Voltage 13
FREQUENCY 15
CPS/Hertz 15
Pitch 15
ANALOG VOICE SIGNAL 17
Complexity 17
Example 17
REVIEW 19
DEFINITIONS 23
Definitions 23
Symbols 23
FREQUENCIES 25
Audible Frequencies 25
Radio Frequencies 25
REVIEW 27
TELEPHONE VOICE NETWORK 31
Inflection 31
Parameters 31
IMPEDIMENTS TO THE SIGNAL 33
Impediments 33
Noise 33

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Loss 33
Distortion 33
Remedies 35
ANALOG AMPLIFIERS 37
Drawback 37
Cumulative Effect 37
REVIEW 39
THE TREND TO A DIGITAL WORLD 43
1960s 43
Transition 43
1970s 43
1980s 43
FACTORS DRIVING NETWORK EVOLUTION 45
Factors 45
Today 45
DIGITAL TRANSMISSION ADVANTAGES 47
Advantages 47
CONSTRAINTS OF DIGITAL 49
Disadvantages 49
REVIEW 51
UNITS OF INFORMATION 55
Introduction 55
Binary 55
Bits 55
Bytes 55
Nibbles 55
Words 55
CHARACTERISTICS OF DIGITAL SIGNALS 57
Characteristics 57
Voltage 57
On/Off 57
Light Switch 57
REVIEW 59
DIGITAL SIGNAL Summary 63
REGENERATIVE REPEATERS 65
Major Advantage 65
Process 65
REVIEW 67
SIGNAL CONVERSION 71

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Coding/ Decoding....71
Process....71
PCM....71
PULSE CODE MODULATION, continued....73
Characteristics....73
REVIEW....75
ANALOG TO DIGITAL CONVERSION....79
PCM STEPS....81
Sampling....81
Quantizing....81
Encoding....81
REVIEW....83
SAMPLING....87
Sampling....87
PAM Signal....87
NYQUIST THEORY....89
Theory....89
Formula....89
Sampling....89
QUANTIZING....91
Measuring....91
ENCODING....93
Encoding....93
Example....93
ANALOG TO DIGITAL CONVERSION - SUMMARY....95
Sampling....95
Quantizing....95
Encoding....95
REVIEW....97
Decoding....101
Filtering....101
WHERE DOES PULSE CODE MODULATION OCCUR?....103
ERROR RATE COMPARISON....105
Average Error Rate....105
Accuracy....105
QUICK SUMMARY....107
Analog Signal....107
Digital Signal....107
A/D Conversion....107

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D/A Conversion..... 107
Digital..... 107
REVIEW 109

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PART A: ANALOG AND DIGITAL SIGNALS

PURPOSE AND PREVIEW

Purpose

The purpose of this section of the module is to provide you with a basic understanding of analog and digital signals. Your will learn the advantages of digital transmission. Your will study the analog-to-digital and digital-to-analog conversion process. These days, most customer calls need to be converted when entering or leaving the Central Office. You will need an understanding of this process in order to correctly analyze trouble.

Preview

Included in this section are the following subjects:

- ✔ Characteristics of the analog signal
- ✔ Definitions
- ✔ The telephone voice network
- ✔ Impediments to the telephone signal
- ✔ Analog amplifiers
- ✔ Evolution of the digital network
- ✔ Advantages and constraints of the digital network
- ✔ Characteristics of digital signals
- ✔ Regenerative repeaters
- ✔ Analog to digital conversion - Pulse Code Modulation
- ✔ Sampling, quantizing and encoding
- ✔ Analog to digital conversion
- ✔ Digital to analog conversion
- ✔ Where conversion takes place

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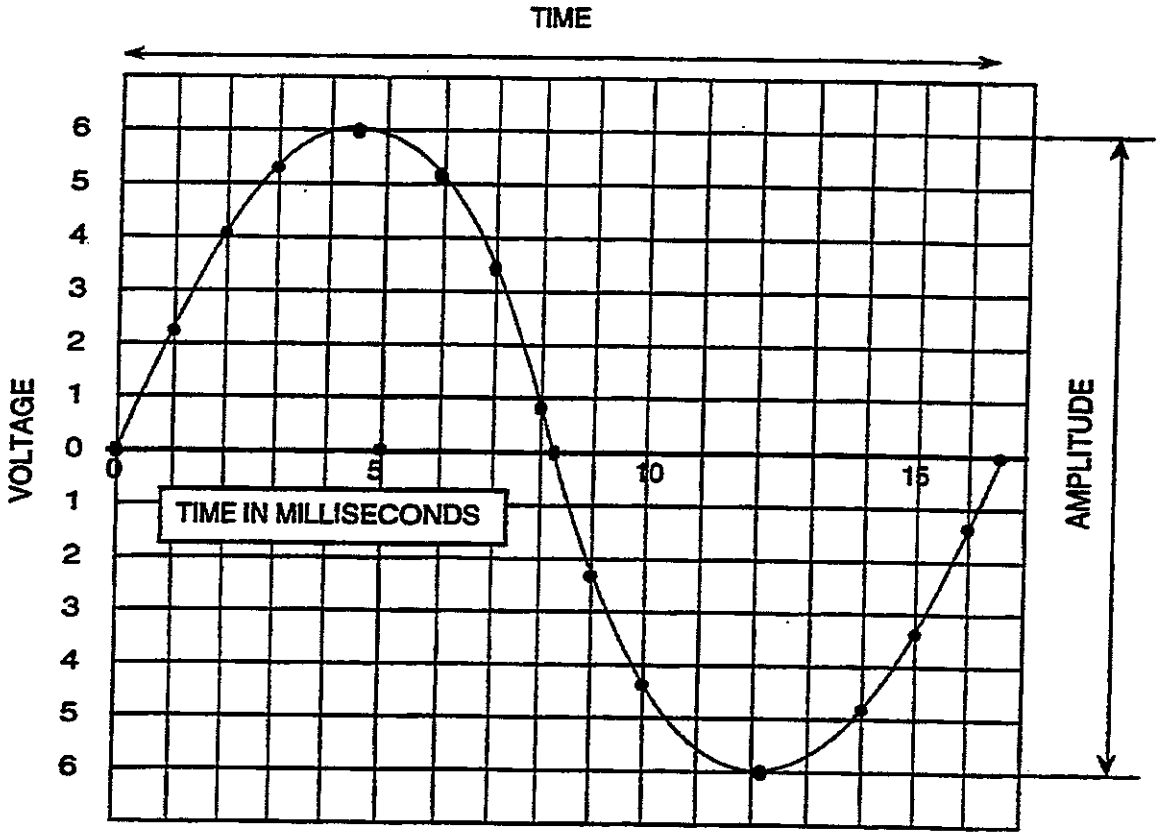
Analog Signal



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TELEPHONE TRANSMISSION

Two Systems

There are two basic types of systems for telephone transmission:

- Analog
- Digital

Current telecommunications systems use a mix of analog and digital signals.

The telephone network was initially designed for voice communications. Therefore, the network was, and still is to some extent, analog in nature. However, we have been steadily evolving to an all-digital world.

Beginning

In order to learn about digital signals, it is first necessary to grasp the concepts of the analog signal. You will then be able to compare and contrast the two types of signals, and understand the equipment necessary to transmit them.

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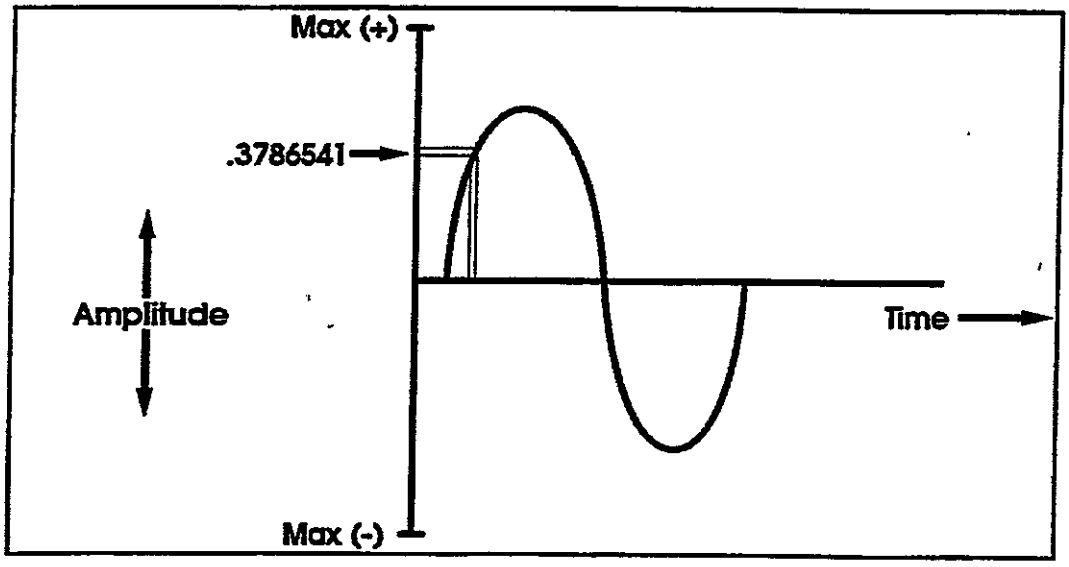
Analog Signal



The analog signal is comprised of continuous and constantly varying voltages.

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THE ANALOG SIGNAL

Overview

An analog signal over a telephone wire is an electrical signal in the form of continuously varying quantities (voltage and frequency), which represents variations in the loudness and pitch of the human voice.

In other words, we use electrical waves to represent (or be analogous to) the acoustical speech waves generated by the human voice.

When converted to electrical energy, the analog signal has continuous voltages that constantly vary. The entire conversation, including pauses, can be represented by some electrical voltage. These voltages constantly vary in value; the illustration shows a hypothetical value at one point in time.

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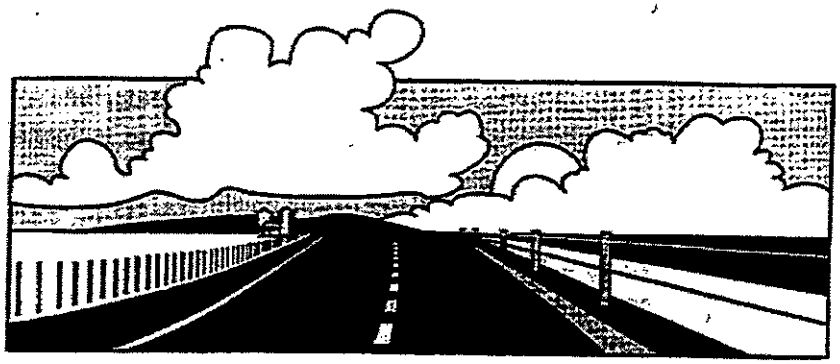

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REVIEW

Complete the review according to the directions provided. Answers are provided on the following page.

Fill in the blank with the appropriate word or phrase.

1) We use electrical waves to represent the acoustical speech waves generated by the human voice.

2) A characteristic of the analog signal is that it has ~~varying~~ continuing voltages.

3) Voltages present in the analog signal constantly change (vary).

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REVIEW - ANSWERS

1) We use electrical waves to **represent or be analogous to (either answer)** the acoustical speech waves generated by the human voice.

2) A characteristic of the analog signal is that it has **continuous** voltages.

3) Voltages present in the analog signal constantly **vary**.

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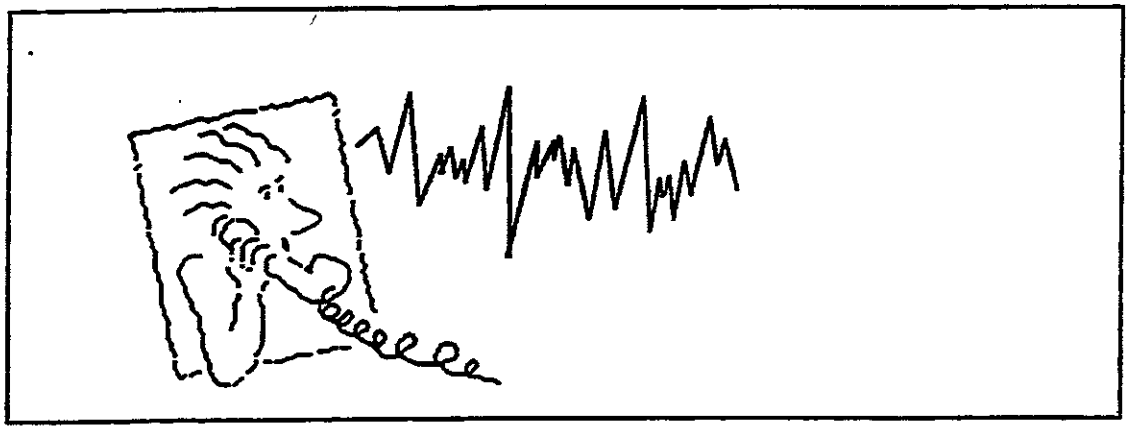
The Analog Signal



Analog signal characteristics:

- Amplitude
- Frequency

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CHARACTERISTICS OF ANALOG SIGNALS

A "picture" of a voice signal has many peaks and valleys, as illustrated. The peaks and valleys change in height and width as the human voice changes in volume and pitch.

Characteristics

We will look at two basic characteristics associated with an analog signal, or sine wave, as it is called. They are:

- ▲ Amplitude
- ▲ Frequency

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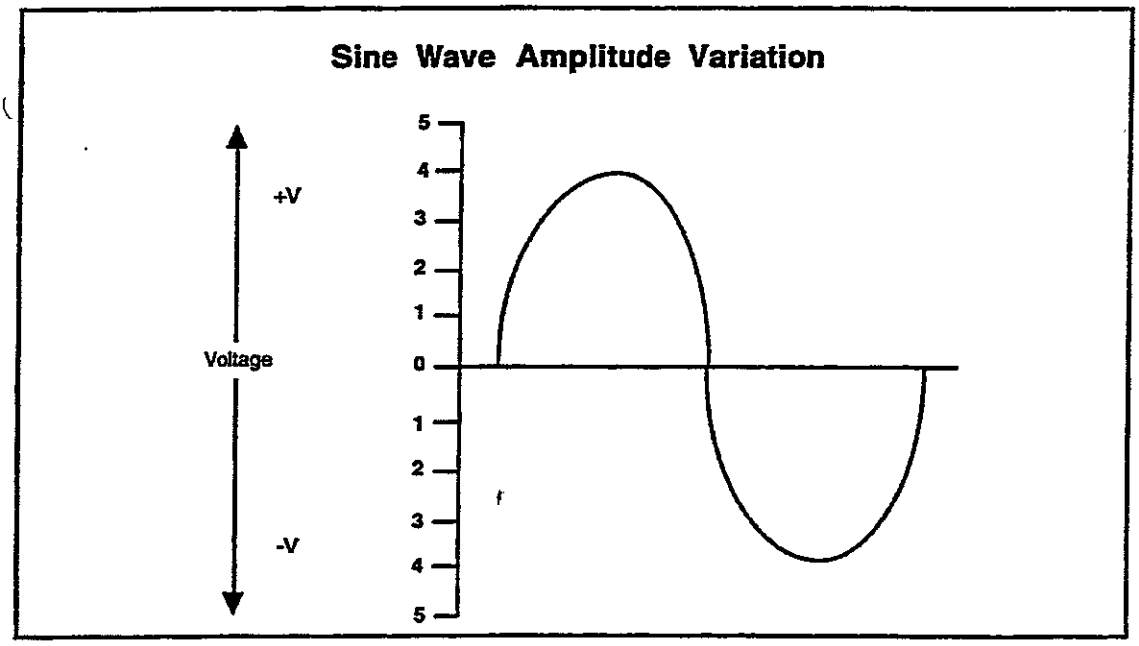
Amplitude



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AMPLITUDE

Overview

The first of the two basic characteristics is the amplitude of the signal. [illegible] can be thought [illegible]. Amplitude is represented by the voltage associated with the signal, as shown in the illustration.

Example

In the example, the curving line is the sine wave. The height of the sine wave represents the amplitude.

Voltage

The signal starts at zero volts and increases to four volts. The signal then decreases in voltage to minus four volts, and then returns to zero volts. At zero volts, the signal has returned to its starting point.

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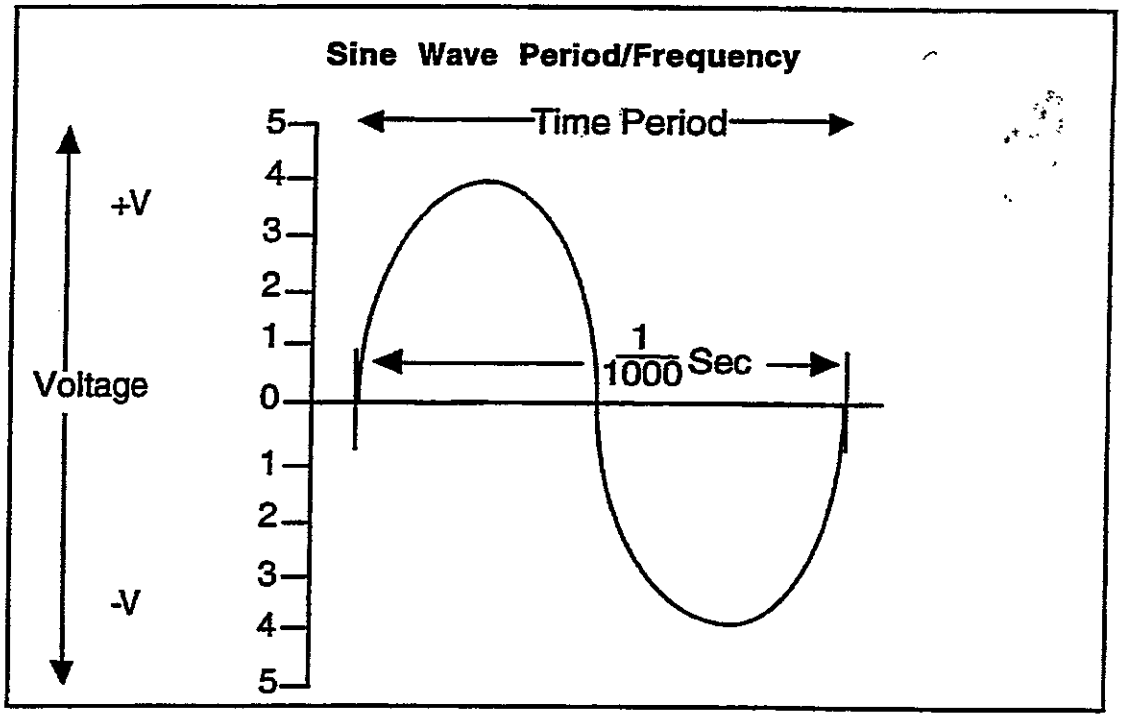
Frequency



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FREQUENCY

The second characteristic of an analog signal, or sine wave, is the frequency of the signal. [redacted]

CPS/Hertz

The time frame used as a reference point is usually one second. Therefore, if the signal repeats itself 1000 times per second it is said to be a "1000 cycles per second signal," or simply "1000 CPS." Another term for Cycles Per Second is hertz (Hz). A 1000 CPS frequency is the same as 1000 Hz.

Pitch

To relate frequency to the human voice, we can say that as the pitch of the voice increases, so does the frequency. [redacted]

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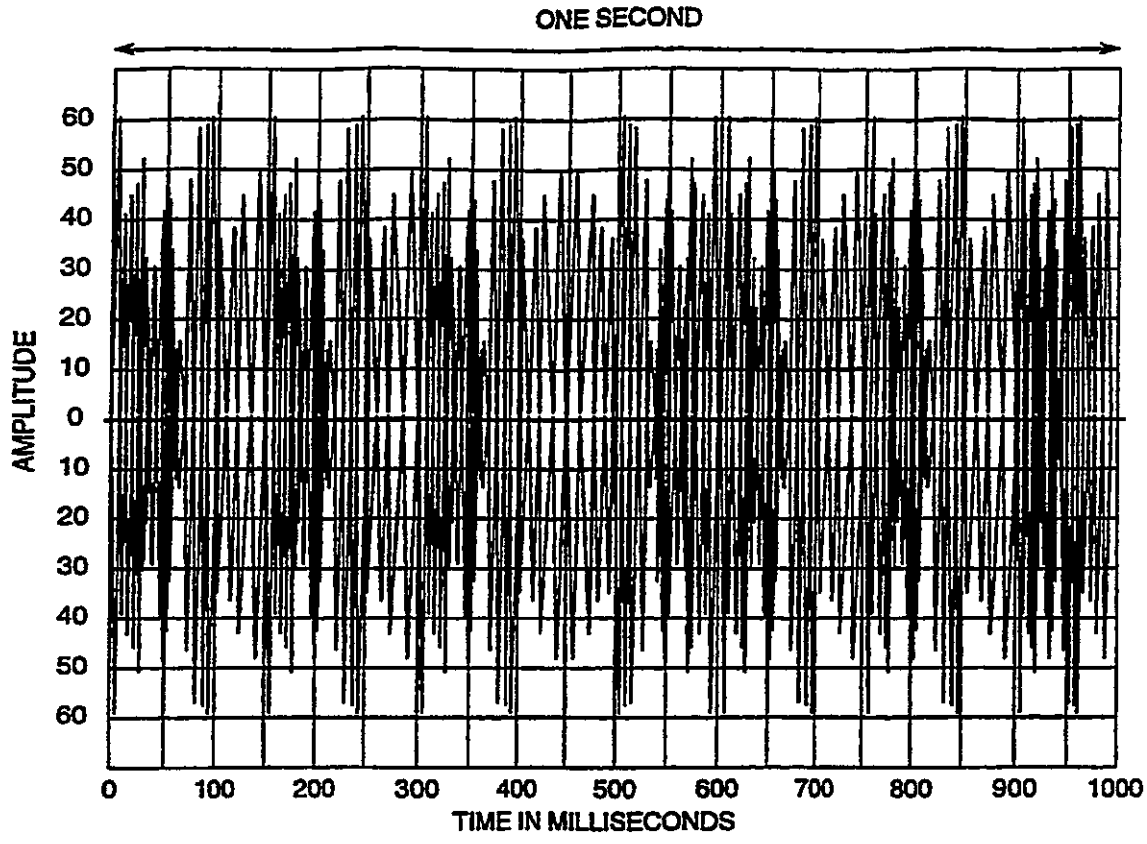
Analog Voice Signal



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ANALOG VOICE SIGNAL

Complexity

The acoustical waves generated by the human voice are very complex. When converted to electrical signals, the voice signal looks like the illustration on the opposite page.

- Each human voice has unique characteristics, depending on their articulation and speech patterns.
- The signal contains a large number of frequency components.
- The components have a wide range of amplitudes.
- The amplitude and frequency change frequently.

Example

Looking at the example, you can see the point we made about the analog signal: it has continuous, constantly varying voltages. You can also see that the frequency is constantly changing.

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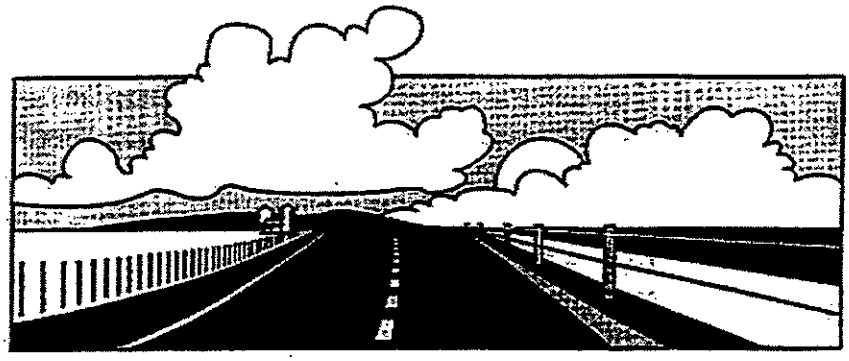

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REVIEW

1) The amplitude of a signal can be thought of as the strength, loudness or voltage associated with that signal.

2) The frequency of a signal is measured by determining how often the signal repeats itself within a given time frame.

3) Each speaker's voice has unique characteristics, depending on their articulation and speech patterns.

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REVIEW - ANSWERS

1) The **amplitude** of a signal can be thought of as the strength, loudness or voltage associated with that signal.

2) The **frequency** of a signal is measured by determining how often the signal repeats itself within a given time frame.

3) Each speaker's voice has **unique** characteristics, depending on their articulation and speech patterns.

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Measurement Terminology

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DEFINITIONS

Definitions

Let's review some terms that will be used in this module.

- **Hertz** is a standard measurement of frequency, which is equal to one cycle per second.
- **Kilo** represents the number 1,000 thousand
- **Mega** represents the number 1,000,000 million
- **Giga** represents the number 1,000,000,000 billion

Symbols

The following are the symbols:

- The symbol for hertz is **Hz**
- The symbol for kilo is **k**
- The symbol for mega is **M**
- The symbol for giga is **G**

These definitions and symbols are universally used in telecommunications. For example, 1,000 hertz is expressed as 1 kHz.

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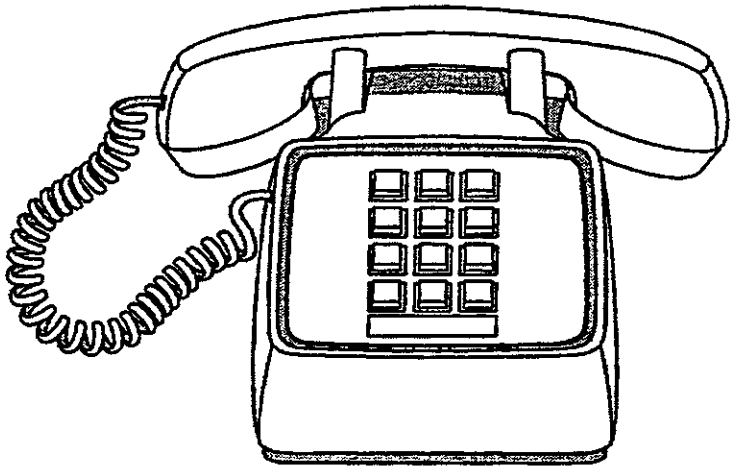
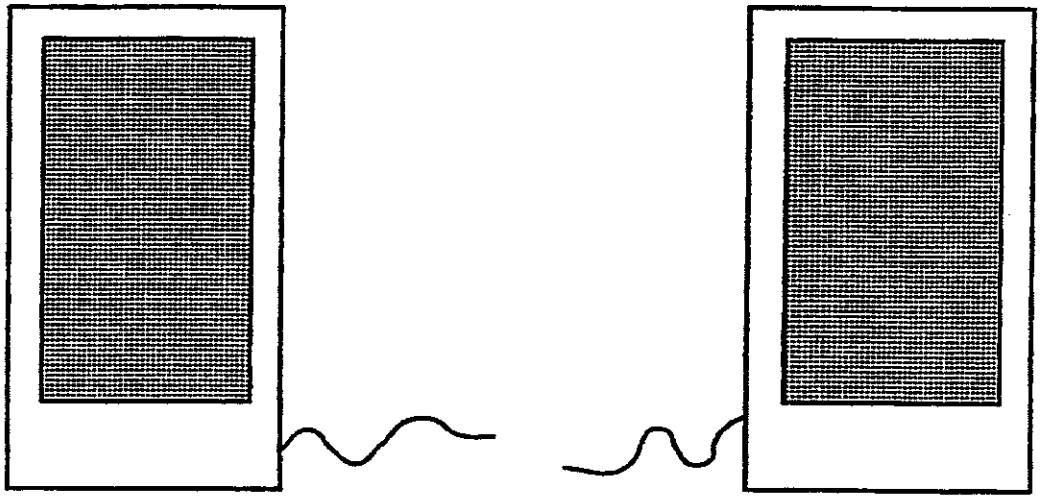
Audible Frequencies



300 - 3300 hertz



35 - 20,000 hertz

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FREQUENCIES

Audible Frequencies

Audible frequencies range from around 20 Hz to 20 kHz. For example, a pair of excellent stereo speakers can accurately reproduce frequencies from about 35 Hz up to 20,000 hertz.

As a comparison, the majority of the voice frequencies carried on telephone transmission fall in a band between 300 Hz and 3300 Hz.

Radio Frequencies

Frequencies between 30 kHz and 300 GHz are considered the radio frequencies. Included in this range are:

- AM radio broadcasts
- FM radio broadcasts
- Television frequencies
- Cellular frequencies
- Microwave frequencies
- Satellite and radar frequencies

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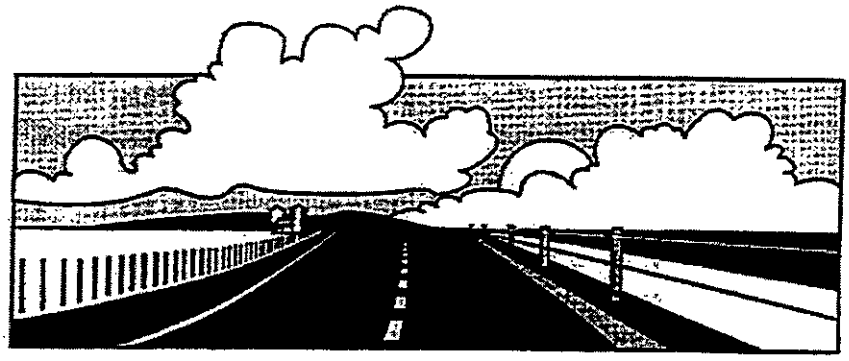

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REVIEW

1) The abbreviation for 20,000 hertz is C.
   b) 2 GHz
   c) 20 kHz
   c) 200 MHz

2) The word, mega, represents the number 1,000,000.

3) Audible frequencies range from 20 Hz to 20 kHz.

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REVIEW - ANSWERS

1) The abbreviation for 20,000 hertz is: **b) 20 kHz**

2) The word, mega, represents the number **1,000,000**.

3) Audible frequencies range from **20 Hz** to **20 kHz**.

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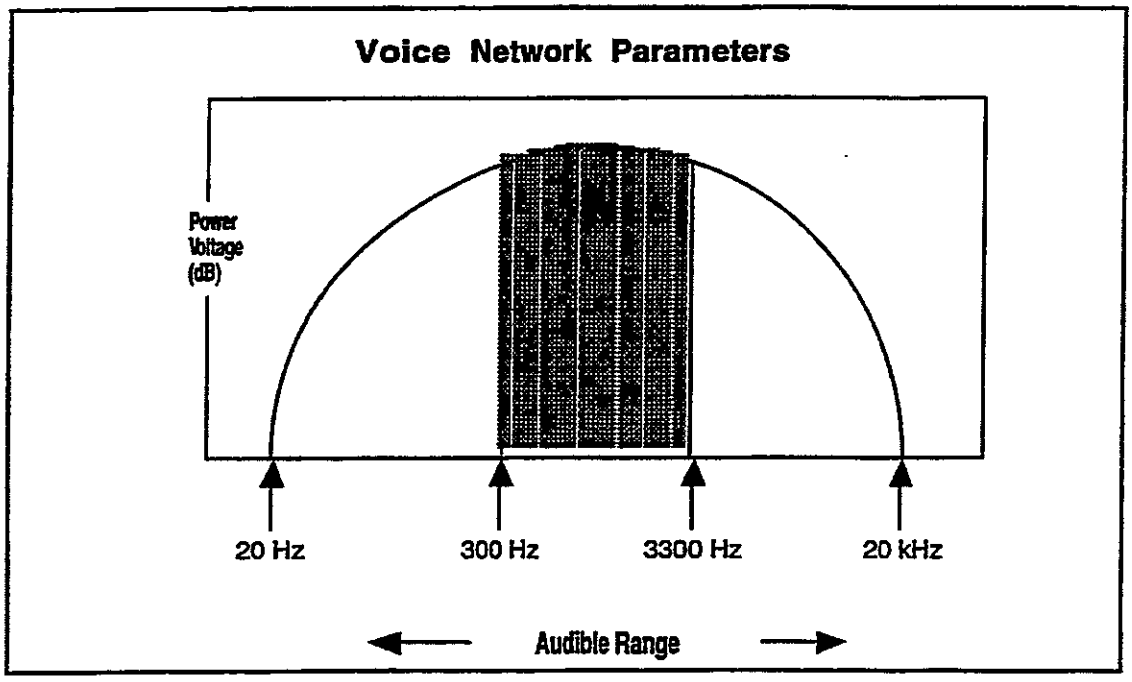
Telephone Voice Network



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TELEPHONE VOICE NETWORK

Inflection

When we speak, our voices vary in both amplitude and frequency. We call this "voice inflection."

The telephone network has been designed to pass speech frequencies that represent the highs and lows of our voice inflection.

Parameters

To ensure a high standard of voice communications capability, voice quality lines are engineered for the 300 to 3300 Hz range, as shown in the illustration. The network has been designed to filter out the frequencies on either side of the 300 to 3300 Hz parameters.

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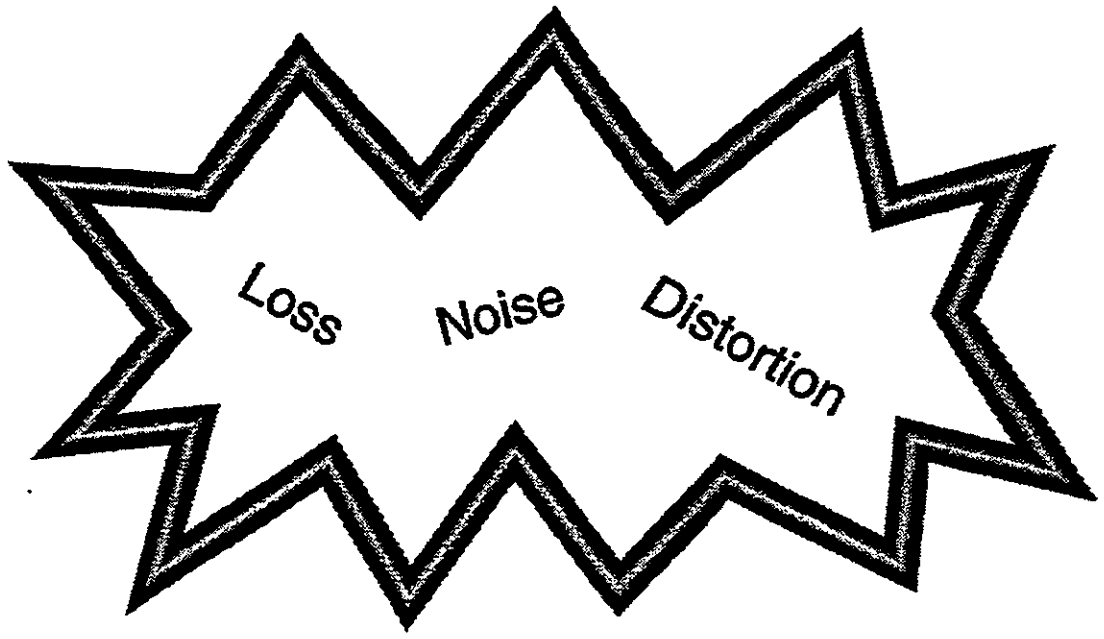
Impediments to the Signal



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IMPEDIMENTS TO THE SIGNAL

Impediments

The purpose of the ideal transmission channel is to deliver an accurate reproduction of the original signal to the receiving terminal. In the telephone world, this would equate to delivering a totally accurate reproduction of a spoken word, or a data signal. There are three major impediments that hamper this effort:

- ▲ Noise
- ▲ Loss
- ▲ Distortion

Noise

Noise is unwanted electrical signals that interfere with the information signal. For example, one might hear clicks or burst of static on the line.

Loss

Loss is defined as the attenuation of the information signal. In other words, the signal gets weaker as it travels distances on the telephone network. No transmission medium has been found which did not lose some of its energy in transit.

Distortion

Distortion changes the information signal waveform, usually in an undesirable fashion. For example, it might increase or decrease the amplitude (volume), or change the frequency.

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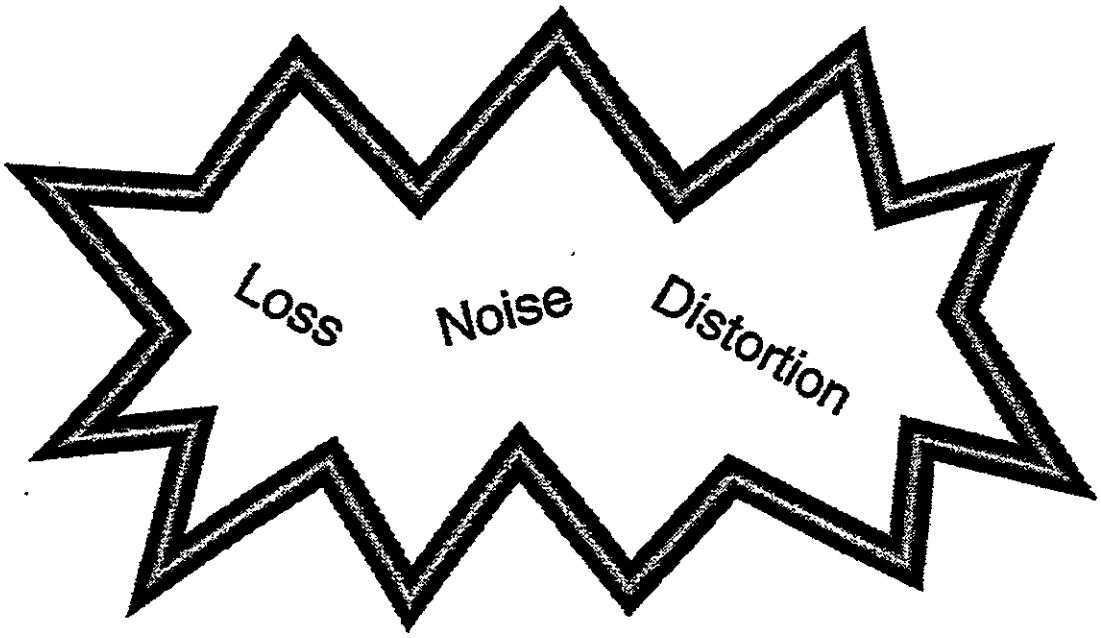
Remedies to Impediments



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IMPEDIMENTS TO THE SIGNAL (continued)

Remedies

Although there are remedies to signal impairments, the perfect transmission has yet to occur. And, even as we remedy certain impairments, other problems arise.

For example, for an analog signal, loss can be overcome by introducing an analog amplifier to restore the signal to its original amplitude.

However, since the amplifier cannot differentiate between signal and noise, it amplifies the noise as well as any distortion in the signal.

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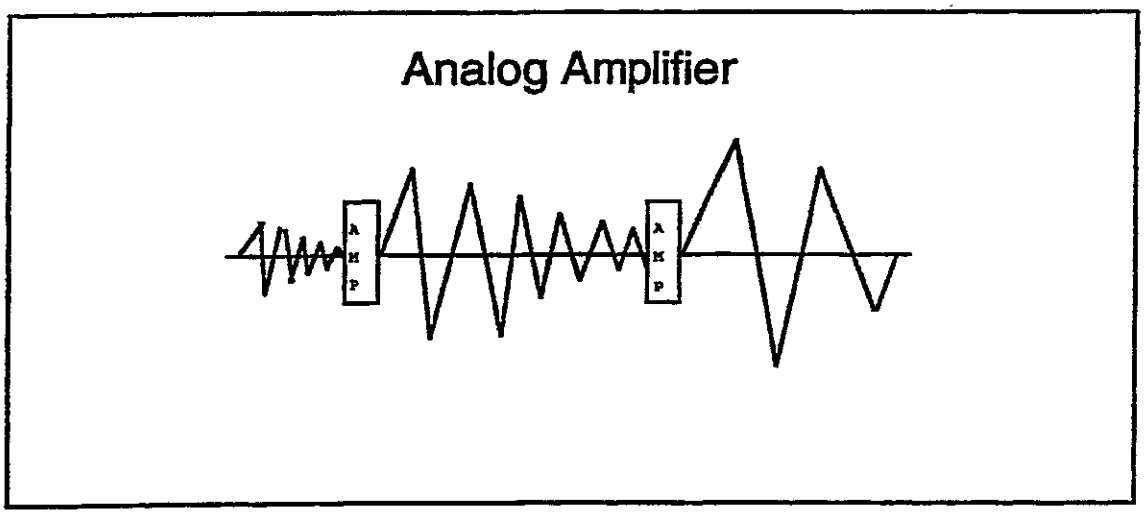
Signal Amplification



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ANALOG AMPLIFIERS

In the illustration, the first amplifier boosts the signal. The second amplifier receives the weakened signal and boosts it again.

Drawback

Unfortunately, any noise that has been picked up along the way is also boosted, as amplifiers are unable to discriminate between noise and voice signals.

This is a major drawback of analog transmission, and one of the reasons for the shift to digital transmission by telephone companies.

Cumulative Effect

The amplified noise and distortion becomes part of the input signal for the next section of the analog transmission line.

As the length of the analog transmission line increases, more amplifiers must be used, and the effect of noise and distortion accumulates.

The cumulative effect of noise and distortion can be minimized by proper system design and component selection — but it cannot be eliminated.

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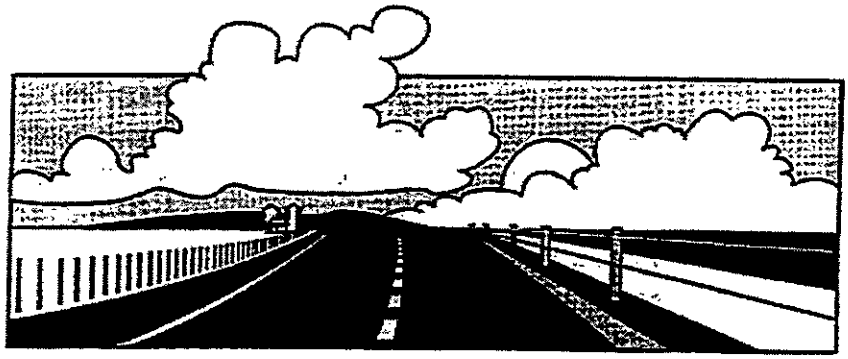

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REVIEW

1) The telephone network has been designed to pass speech frequencies that represent the highs and lows of voice inflection.

2) Voice quality telephone lines are engineered for the frequency range of 300 Hz or 3300 Hz.

3) The purpose of the ideal transmission channel is to deliver an accurate reproduction of the original signal to the receiving terminal.

4)

Noise c	a)	The attenuation of the information signal.
Loss a	b)	A change in the information signal waveform.
Distortion b	c)	Unwanted electrical signals that interfere with the information signal.

5) The drawback to analog amplifiers is that as they boost the signal they also boost noise.

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REVIEW - ANSWERS

1) The telephone network has been designed to pass the frequencies that represent the highs and lows of voice **inflection**.

2) Voice quality telephone lines are engineered for the frequency range of **300 Hz** to **3300 Hz**.

3) The purpose of the ideal transmission channel is to deliver an accurate **reproduction** of the original signal to the receiving terminal.

4) Noise **c**
Loss **a**
Distortion **b**

5) The drawback to analog amplifiers is that as they boost the signal they also boost **noise**.

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A Digital World

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THE TREND TO A DIGITAL WORLD

1960s

Until the 1960s, telephone systems were designed to transmit and switch only analog electrical signals. In the 1960s, the network was made up of analog electromechanical switching systems, interconnected by analog transmission systems.

Transition

The transition from analog to digital electronics began when the economy and reliability of solid-state electronics made digital transmission feasible.

In the mid-to-late 1960s, digital transmission was introduced. T-Carrier (discussed later) enabled telephone subscribers to share transmission facilities.

1970s

During the 1970s, the telecommunications industry began using digital electronics for switching as well as transmission. Use of digital interoffice facilities (interoffice trunks) increased in the metro and outstate areas.

1980s

In the 1980s, use of digital toll switches and digital interoffice facilities continued to expand. Local digital switches were introduced. The digital transmission technology used in interoffice facilities migrated to the local loop.

Each year, more digital equipment replaces analog equipment, moving the industry closer to all-digital networks:

- ✔ Digital switching in the Central Office
- ✔ Digital interoffice facilities
- ✔ Digital transmission in the local loop

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Network Evolution

Factors driving network evolution:

- ★ Technology
- ★ New features
- ★ Cost reduction
- ★ Service improvement

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FACTORS DRIVING NETWORK EVOLUTION

Factors

Other factors, beside technology, drove the evolution of network:

★ New features - a digital world means the availability of new features, including CLASS features (such as Caller ID) and digital data services (such as DS1 Service).

★ Cost reduction - digital technology led to better use (that is, more efficient use) of plant, lower up-front costs, and lower operating costs.

★ Service improvement - the transition to digital led to improved service quality, as perceived by customers. Digital switches provide more reliable switching, and faster provisioning.

Today

Digital Central Offices abound in metro areas, and conversion to digital offices in rural areas is a major on-going project in many towns and is complete in some others.

Gary Duffy of U S WEST summarized the trend to digital: "When we look at all the economic drivers in our studies, digital easily beats out analog. It's less expensive to maintain and easier to add new applications, which means the customer can get the new kinds of services they'll want."

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Advantages of Digital Transmission:

- ✔ Freedom to transmit any signal (voice, data, video)
- ✔ Signals less effected by noise and distortion
- ✔ More cost-effective than analog
- ✔ Superior transmission quality
- ✔ Testing and maintenance improvements
- ✔ Transmission and switching functions can reside in the same equipment

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DIGITAL TRANSMISSION ADVANTAGES

Advantages

Digital transmission has many advantages. Let's briefly discuss some of them.

- ✔ Digital allows the transmission of any signal whatsoever. Voice, data and video all look the same in digital: 1s and 0s.
- ✔ As we mentioned previously, on an analog signal, noise is amplified and has distance limitations due to the need for amplification. With digital's regenerative repeaters (discussed shortly), the signal is completely regenerated, so its less affected by loss and noise.
- ✔ Digital's cost is reduced, mainly due to multiplexing (multiplexing will be discussed later in the module). In addition, relatively simple network components can be built to recognize and process digital signals, saving on equipment costs.
- ✔ With digital circuits came improved, automatic testing capabilities. This led to improve circuit maintenance.
- ✔ Transmission and switching functions can reside in the same equipment, reducing the overall amount of necessary equipment.

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Constraints of Digital:

- ✘ Need for synchronized timing devices
- ✘ Requires more bandwidth
- ✘ Expensive analog/digital interfaces

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CONSTRAINTS OF DIGITAL

Disadvantages

The disadvantages of using digital electronics include:

- ✘ Timing devices must synchronize some digital transmissions. Each one or zero is critical in digital transmission. Transmitting and receiving equipment must be carefully synchronized to ensure that every one or zero transmitted is received.
- ✘ Digital requires more bandwidth. Whereas the range of frequencies that can be transmitted determines analog bandwidth, digital bandwidth is determined by the rate at which bits can be transmitted.
- ✘ Conversion equipment is required to interface with the existing analog network. Interfaces between digital and analog equipment can be expensive.

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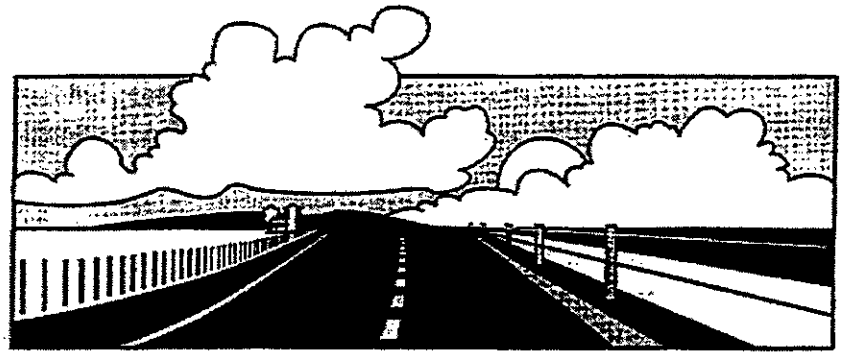

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REVIEW

1) The transition from analog to digital began when the economy and reliability of Solid-State electronics made digital transmission possible.

2) Other factors, besides technology, drove the evolution of the digital network. List at least one of these factors.
new features, cost reduction

3) Digital allows the transmission of any signal.

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REVIEW - ANSWERS

1) The transition from analog to digital began when the economy and reliability of **solid state** electronics made digital transmission possible.

2) Other factors, besides technology, drove the evolution of the digital network. List at least one of these factors. **Any one of the following is an acceptable answer: new features; cost reduction; or service improvement**.

3) Digital allows the transmission of **any** signal.

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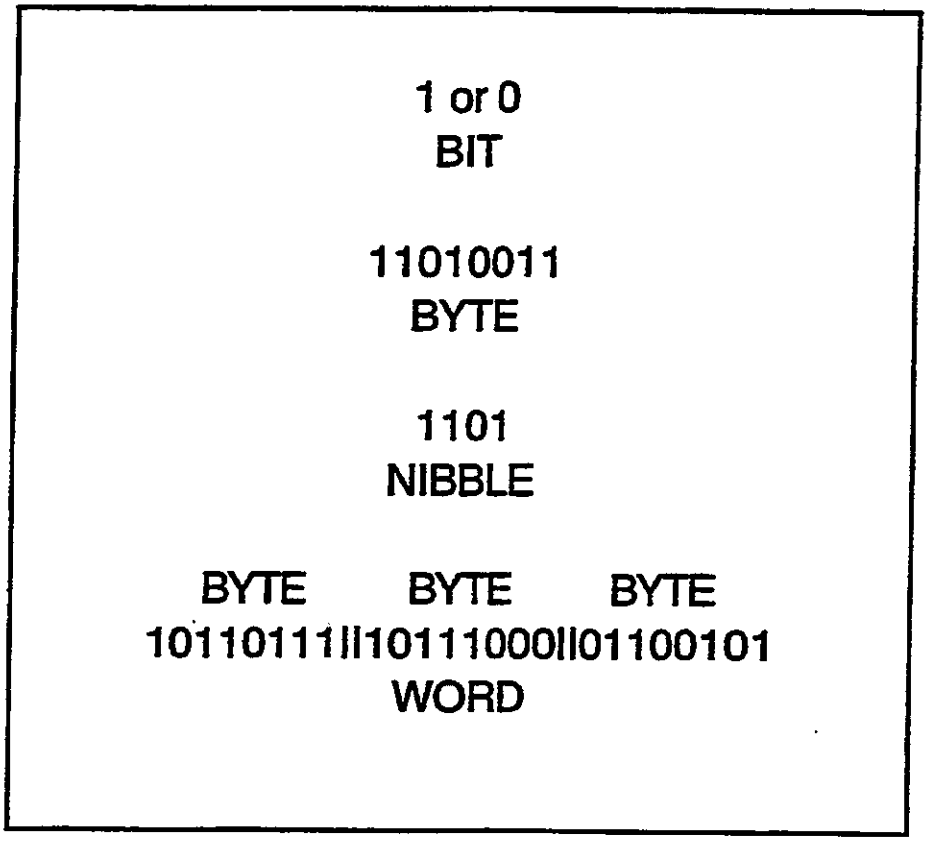
Units of Information



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UNITS OF INFORMATION

Introduction

Before we discuss digital signals, it may be helpful to discuss the units of information used in the digital process.

In digital equipment such as computers, numbers are stored internally via electrical voltages. These voltages can be on or off, high or low, 0 or 1. Thus, all information to be used by the computer is coded into zeros and ones.

Binary

Webster's defines binary as being "compounded or consisting of or marked by two things or parts." As the binary numbering system uses only zeros and ones, computers use only zeros and ones to represent data.

Basic units of data are called bits, bytes, nibbles, and words, as shown in the illustration.

Bits

The smallest unit of information used by computers is a bit, which is the abbreviation for binary digit. A bit is either of the two digits in the binary numbering system, a 1 or a 0.

Bytes

The smallest unit of information a computer can store and retrieve is one byte, which is made up of eight bits. Each byte represents an alphabetical/numerical character.

Nibbles

A nibble is a half byte or four bits.

Words

A computer word may be eight bits long (a byte) or it may be longer. Word length varies from one machine to another. Longer words are often divided into bytes. We will frequently refer to 8-bit words.

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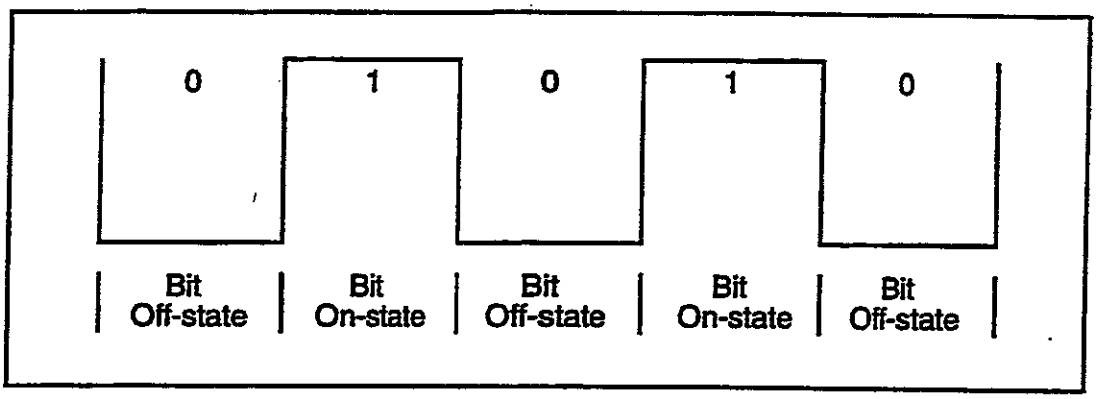
Digital Signal



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CHARACTERISTICS OF DIGITAL SIGNALS

Now let's look at the characteristics of the digital signal.

Characteristics

Unlike the analog signal which continuously rises and falls as it represents the human voice, a digital signal is always the same height. Instead of curving like a sine wave, a digital signal is always straight up and down, flat at the top, and the same width, as shown in the illustration.

A digital signal does not vary in the characteristics of analog signals: amplitude and frequency.

Voltage

A digital signal consists of a voltage, from zero volts to its rated voltage.

On/Off

As shown in the illustration, when a voltage is present for a specified period of time, a 1 (one) is generated - signifying ON. When a voltage is absent for the same period of time, a 0 (zero) is generated, signifying OFF.

Light Switch

Another way to think of a digital signal is to think of a light switch. Either the light is on, or the light is off. The same principle applies to the transmission of digital signals. Digital signals are non-continuous signals. The voltage is either present, or not present. You see the signal for a short period of time, and then the line will actually have nothing on it for a time.

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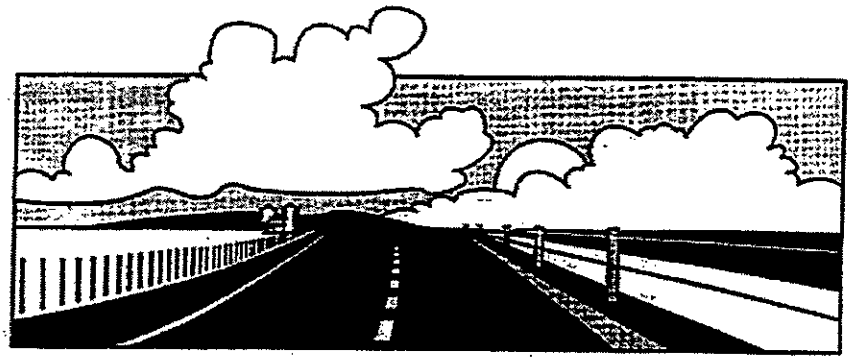

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REVIEW

1) Computers use binary digits to represent data.

2) The smallest unit used by computers is the bit, the value of which is either a 0 or a 1.

3) The smallest unit of information a computer can store and retrieve is the byte, which is made up of 8 bits.

4) A digital signal has only two values; they are d.
   a) 1 or 0
   b) On or off
   c) Voltage or no voltage
   d) Any of the above

5) Unlike the human voice that continuously rises and falls, a digital signal is always the same height.

6) For a digital signal, when a voltage is present for a specified period of time, a 1 is generated.

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REVIEW - ANSWERS

1) Computers use **binary** digits to represent data.

2) The smallest unit used by computers is the **bit**, the value of which is either a **one** or a **zero**.

3) The smallest unit of information a computer can store and retrieve is the **byte**, which is made up of 8 **bits**.

4) A digital signal has only two values; they are **d - Any of the above**.

5) Unlike the human voice that continuously rises and falls, a digital signal is always the same **height**.

6) For a digital signal, when a voltage is present for a specified period of time, a **one** is generated.

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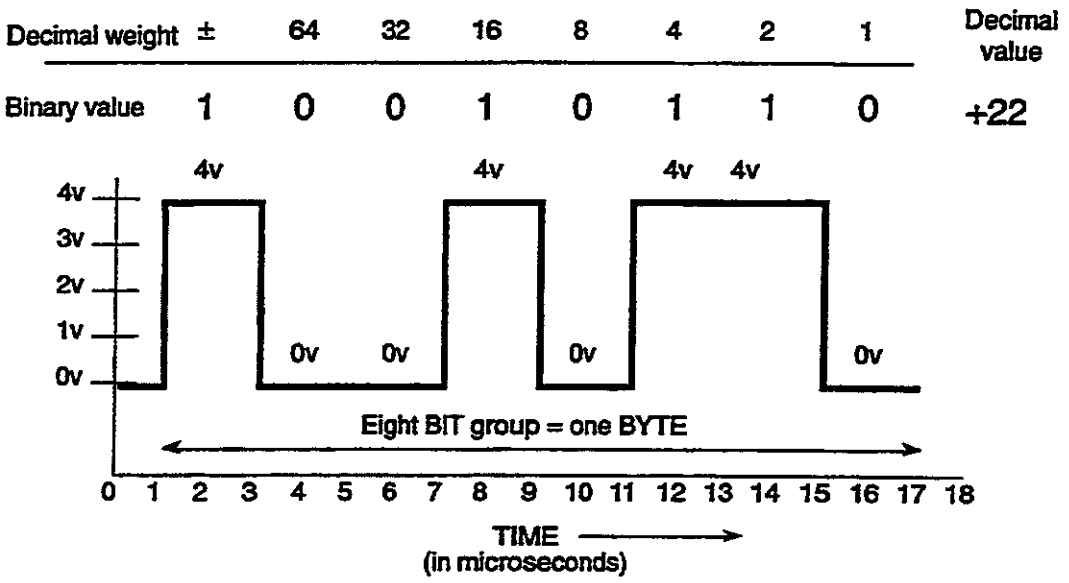
Digital Signal



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DIGITAL SIGNAL SUMMARY

To review, a digital signal is made up of a combination of separate parts called binary digits or bits. A bit can have only two values: 0 and 1, on and off, voltage and no voltage. The values can be represented by values of voltages, as shown in the illustration. The "1" or "ON" value is represented by 4v (4 volts) and the "0" or "OFF" value is represented by 0v.

The digital signal is changing from the 0 level and to the 1 level and back again as time passes. The binary values are listed above the signal.

In the example, the binary value of the signal is 1 0 0 1 0 1 1 0. The first seven bits, counting from right to left, represent the value of the data. The last or eighth bit signifies whether the data is positive or negative. Eight bits are equal to one byte of data.

The binary number can be converted to a decimal number by giving each bit a decimal weighting. The decimal weight is listed above each binary position. The decimal value of this binary word or byte is +22. You will see the value of this when we discuss the analog to digital conversion process.

You will learn how to convert binary numbers into decimal values in a later module.

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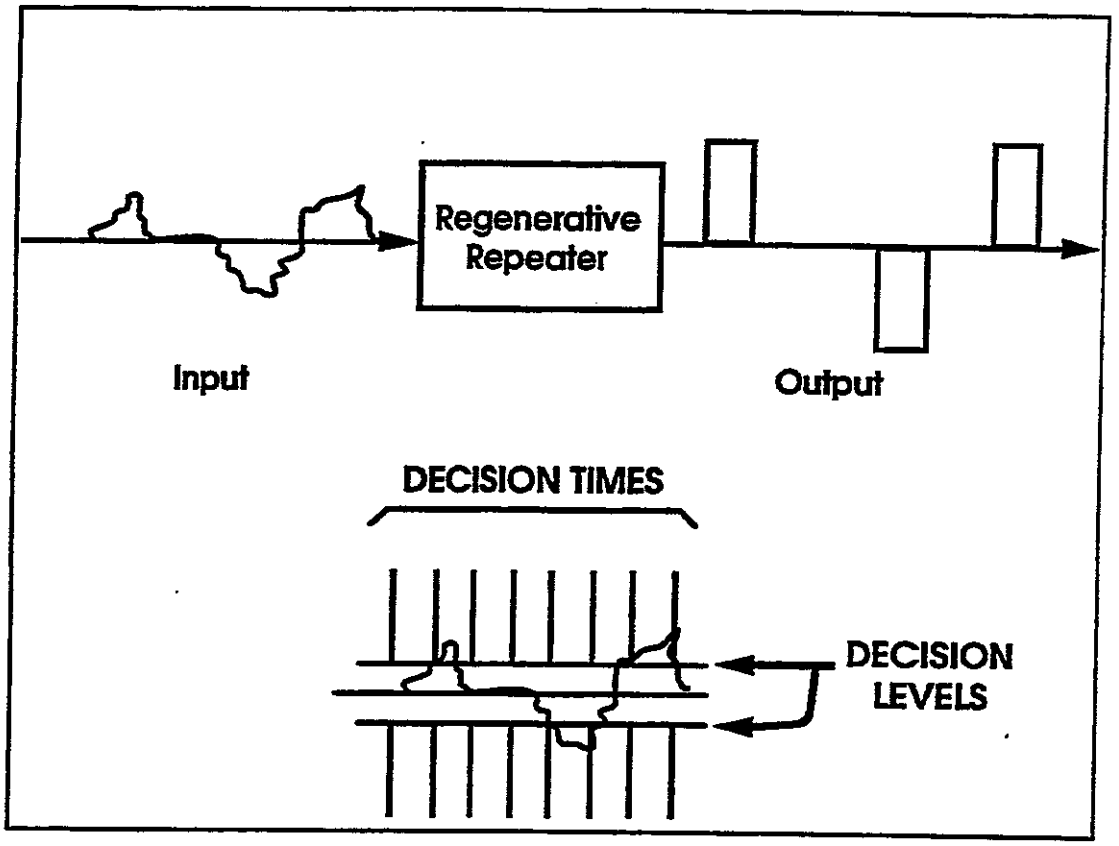
Regenerative Repeater



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REGENERATIVE REPEATERS

The same impairments (loss, noise and distortion) await the digital signal, just as they do for analog. The digital signal leaves the transmitter as perfect ones and zeros, represented by pulses of electricity for the ones, and ground potential for the zeros. The signal does not travel far before loss, noise, and distortion take their toll.

Major Advantage

The major advantage of digital transmission is the ability to control signal loss, noise and distortion through the use of regenerative repeaters. A regenerative repeater, often simply called a repeater, does not merely amplify the signal; it regenerates or makes a new signal.

Process

When the digital signal, distorted by the loss, noise, and distortion characteristics of the transmission line, arrives at the input of the regenerative repeater, it is examined at each bit position, as shown in the lower illustration:

If the input signal exceeds a designed decision level, the repeater decides there is a pulse in that position, and the repeater generates a new pulse.

If the input signal does not exceed a designed decision level, the repeater decides there is no pulse in that bit position, and no pulse is generated.

In this manner, the digital signal is regenerated (rather than just amplified) at each repeater, and the effects of transmission impairments on the waveform are controlled. The signal is repaired, instead of just made louder. This process can be done over and over, regardless of the length of the circuit.

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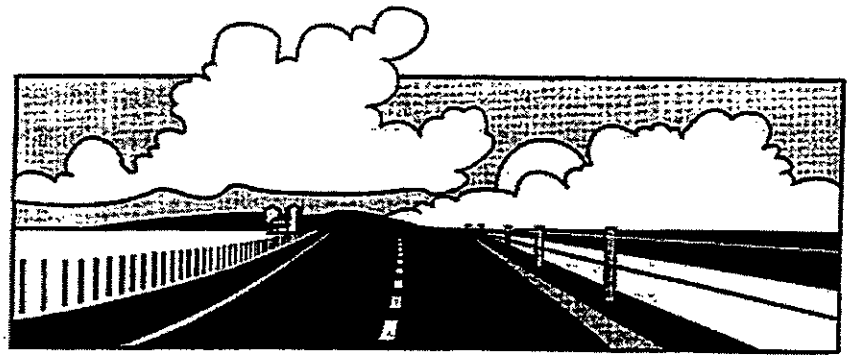

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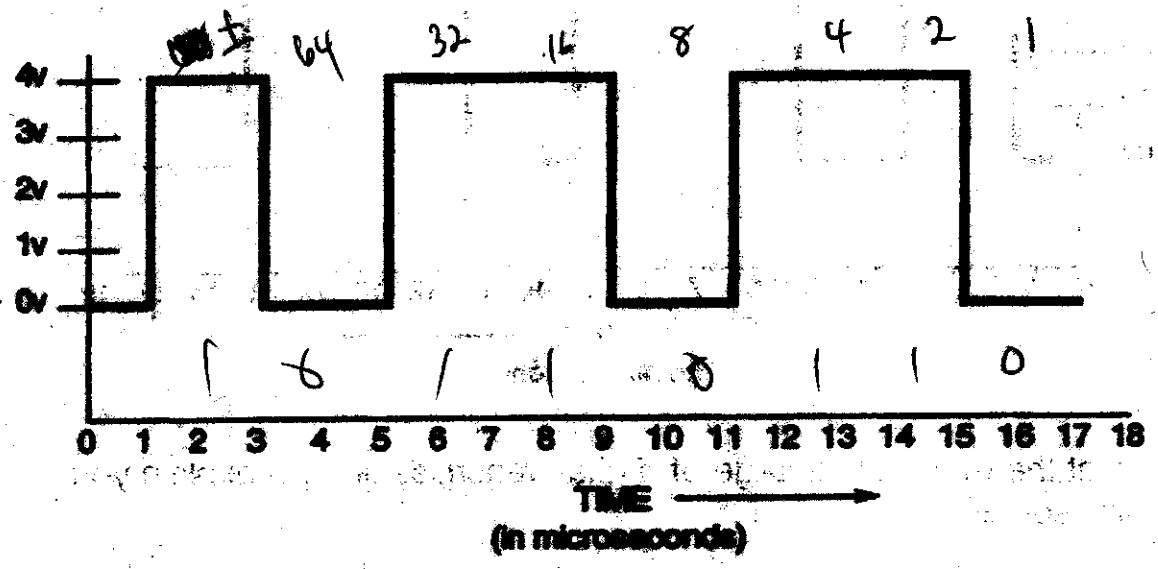
REVIEW

Look at the diagram and answer the following question.

1) The following diagram is similar, but not the same as, the diagram used earlier to illustrate binary value. Looking at this illustration, what is the binary value of the digital signal? (Assume that the signal starts at time marker 1.) 1 0 1 1 0 1 1 0



2) List the major advantage of digital transmission and explain your reason why.

digital transmission accurately reproduces a signal regardless of distance.

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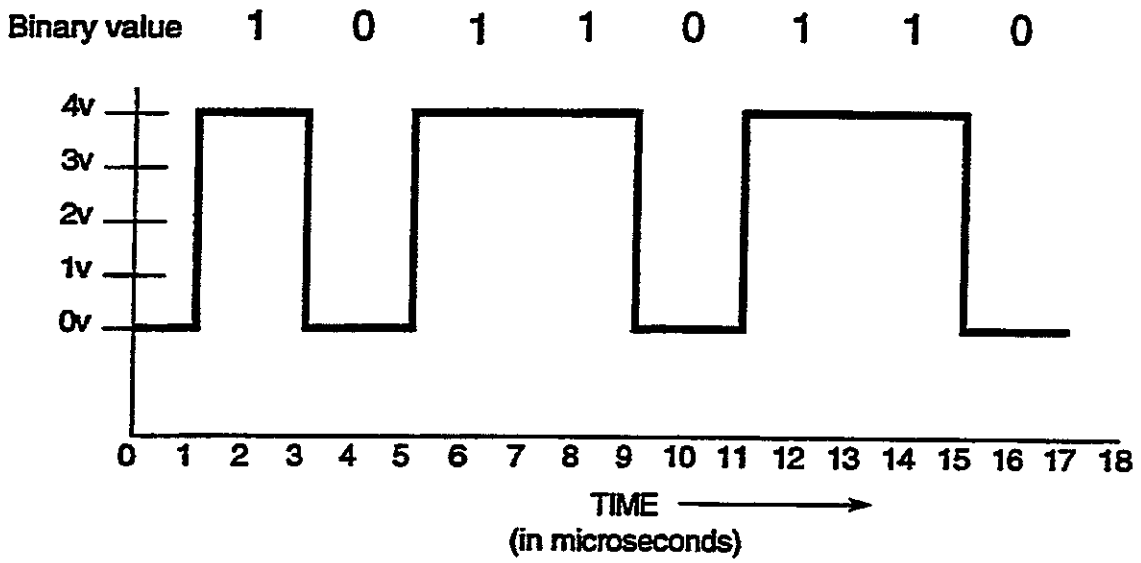
REVIEW - ANSWERS

1) What is the binary value of this digital signal? **10110110**



2) List the major advantage of digital transmission and explain your reason why.

The major advantage of digital transmission is the ability to control signal loss, noise and distortion through the use of regenerative repeaters. A regenerative repeater does not merely amplify the sound; it regenerates or makes a new signal.

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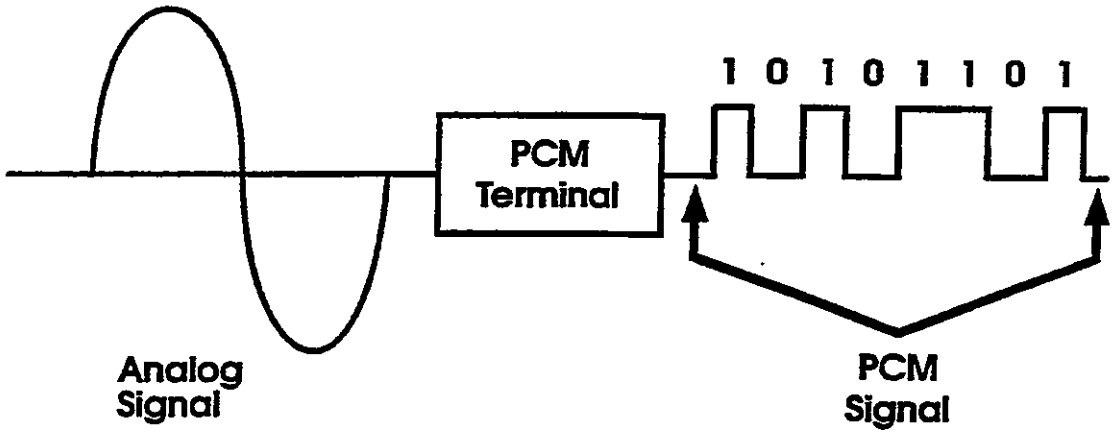
Pulse Code Modulation



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SIGNAL CONVERSION

Analog signals cannot be transmitted over a digital telephone line. In order to transmit an analog signal over a digital telephone line, the analog signal must be converted to digital.

Coding/ Decoding

The process of converting from analog to digital is called coding (also called encoding).

The signal can then be converted back to analog. This conversion process is called decoding.

Process

The coding/decoding process uses CODEC equipment. CODEC stands for coder/decoder. CODEC is a generic term for the equipment that converts analog signals into digital for transmission over digital lines; it can also convert the digital signal back to analog at the distant end.

PCM

In the graphic, we see an analog signal being converted into a digital signal. In this case, the process being used is known as Pulse Code Modulation (PCM). Although there are other methods by which an analog voice can be converted to digital, Pulse Code Modulation is the industry standard today.

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Characteristics of PCM

- Uses binary numbers to represent speech
- Pulses are equal height and width
- Information represented by presence or absence of pulses

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PULSE CODE MODULATION, CONTINUED

Characteristics The characteristics of PCM are as follows:

- PCM uses 8-bit binary numbers to represent periodic samples of the speech signal (or analog signal). Why? Because binary numbers can be transmitted with pulses of electricity.
- The pulses are of equal height and width.
- The information content of the digital (or PCM) signal is carried by the presence or absence of the pulses - not the shape of the pulses.

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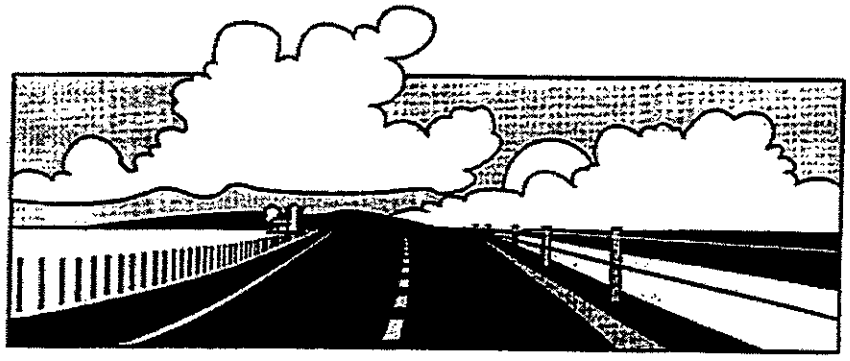

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REVIEW

1) The process of converting the analog signal to digital is called b.
   a) digitization
   b) coding
   c) pulsation

2) The industry standard for the process of converting the analog signal to digital is PCM.

3) Binary numbers are used to represent periodic samples of the speech signal. Why?
   It is the process of digitization, or coding, of the analog speech signal - transmission with pulses,

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REVIEW - ANSWERS

1) The process of converting the analog signal to digital is called **b) coding**.

2) The industry standard for the process of converting the analog signal to digital is **Pulse Code Modulation (PCM)**.

3) Binary numbers are used to represent periodic samples of the speech signal. Why? **Binary numbers can be transmitted with pulses of electricity.**

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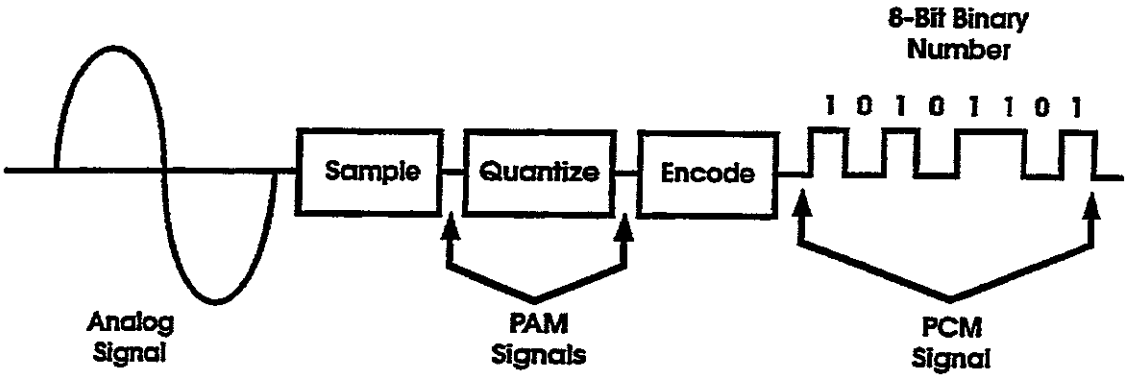
Analog to Digital Conversion



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ANALOG TO DIGITAL CONVERSION

Let's look at the process of converting the analog signal to digital (in this case, Pulse Code Modulation, or PCM).

Speech signals start at the transmitter of a telephone set as an analog signal. To carry the "information" in the analog signal over a digital transmission line, it is necessary to convert the analog signal to a digital one. The process we use is PCM.

Example

Note the three boxes in the illustration, between the analog signal and the digital signal. They represent the three steps in converting an analog signal to digital:

★ Sample

★ Quantize

★ Encode

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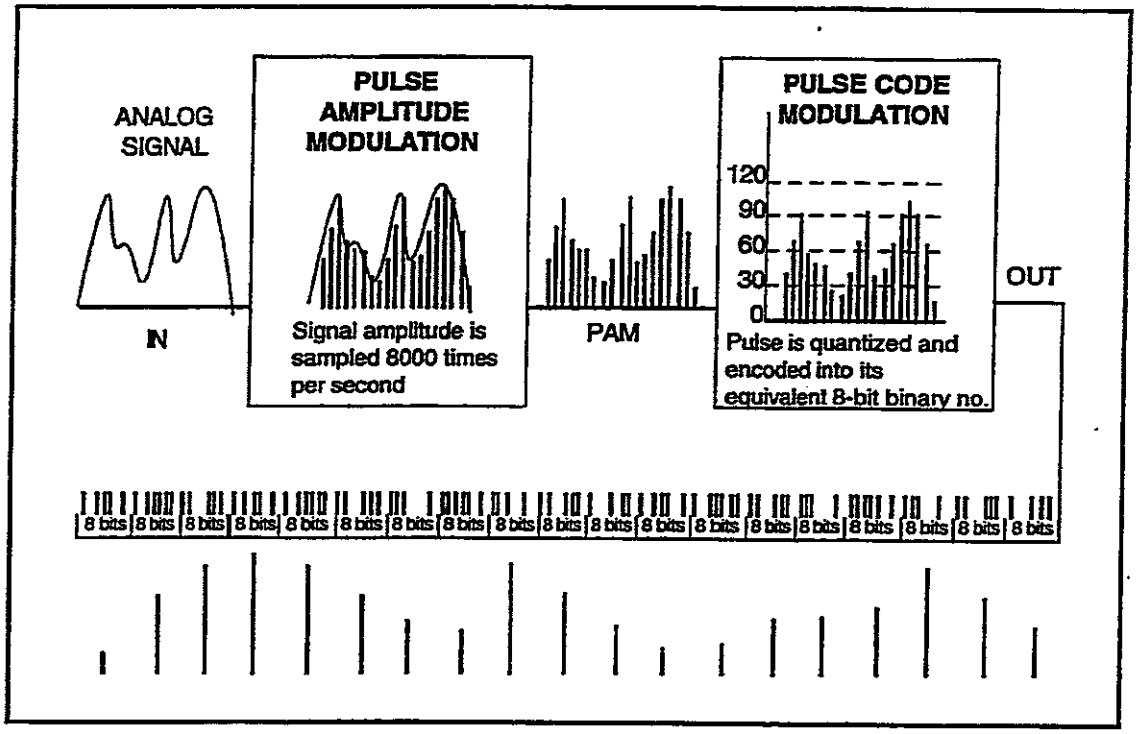
Steps in Pulse Code Modulation



Steps in Pulse Code Modulation:

1. Sampling
2. Quantizing
3. Encoding

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PCM STEPS

PCM essentially uses three steps in the analog to digital conversion:

Sampling

1. The analog signal is sampled periodically. Each sample generates a Pulse Amplitude Modulation (PAM) signal, which is a crude type of digital signal in itself. It has an amplitude equal to the amplitude of the analog signal. This step is known as sampling.

Quantizing

2. The amplitude of the PAM signal is "measured" to derive a decimal number that represents its amplitude level. To measure the signal, it is matched to a segmented scale. The idea here is to measure the amplitude of each PAM signal. This step is known as quantizing.

Encoding

3. The decimal number derived in the quantizing step is then converted to its equivalent 8-bit binary number. A binary number can be represented by pulses of electricity. This step is known as encoding.

Since this process converts one instantaneous value of the analog signal into an 8-bit binary number, it is necessary to repeat the process many times a second.

Sampling » Quantizing » Encoding

These are the very important basics of digital communications. Now that you have an overview of the process, let's look closer at the individual steps. But first, a review!

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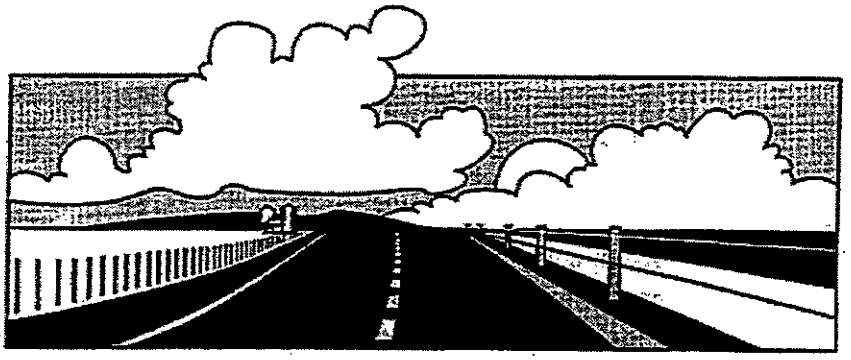

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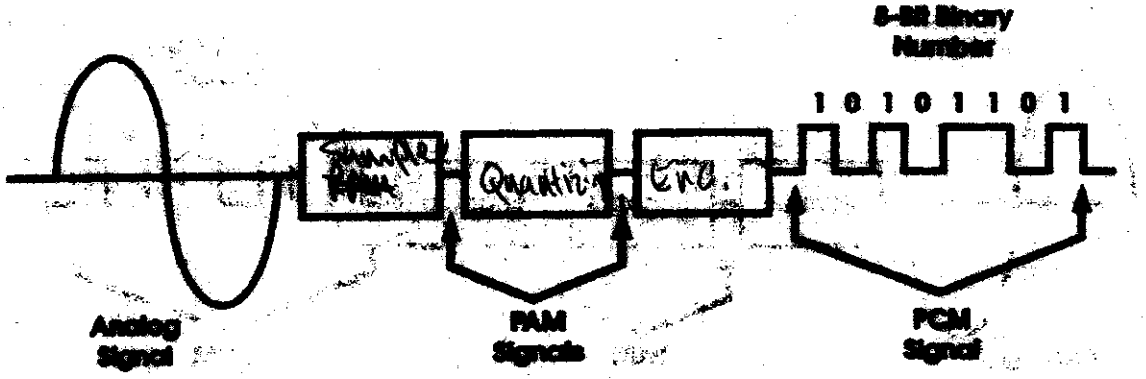
REVIEW

1) The first step in the analog-to-digital conversion process, which yields a crude type of digital signal, generates a PAM signal.

2) There are three steps involved in converting the analog signal to digital. Identify them, in order, by labeling the three blank boxes below.



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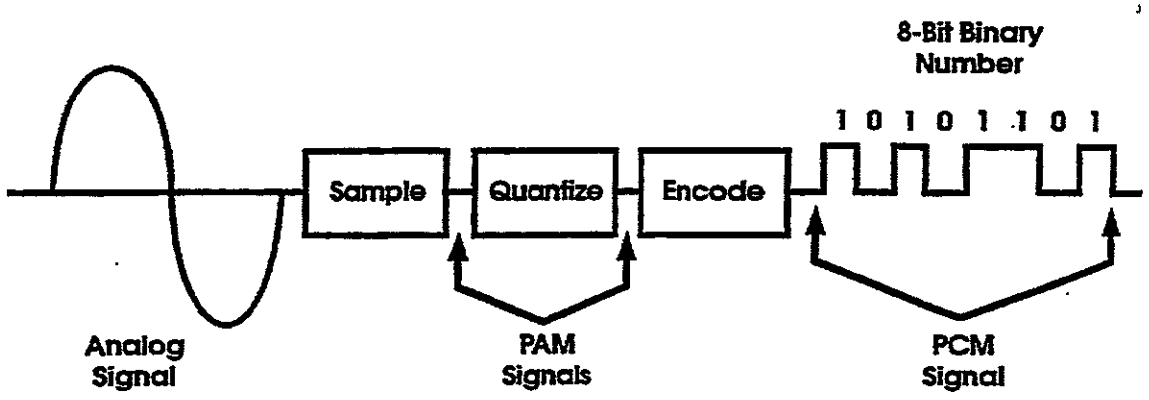
REVIEW - ANSWERS

1) The first step in the analog-to-digital conversion process, which yields a crude type of digital signal, generates a **PAM (Pulse Amplitude Modulation)** signal.

2) There are three steps involved in converting the analog signal to digital. Identify them, in order, by labeling the three blank boxes below.



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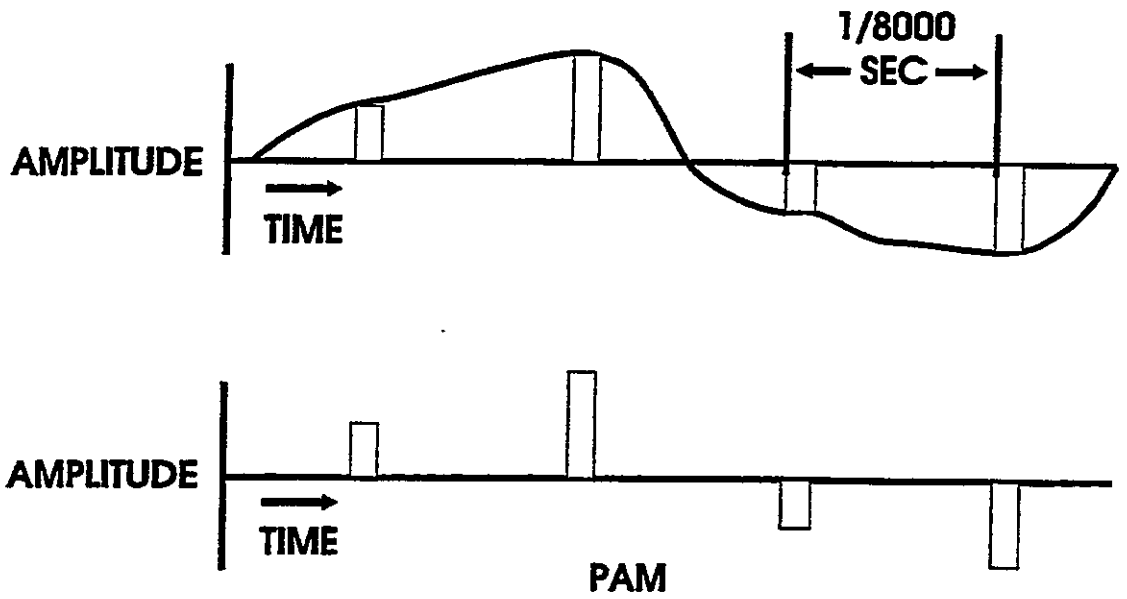
Sampling



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SAMPLING

Sampling

The first step in the analog-to-digital conversion is sampling. The analog signal is sampled periodically to determine its instantaneous value at different points in time, as shown in the illustration.

PAM Signal

Each time the signal is sampled, we generate a PAM (Pulse Amplitude Modulation) signal. The PAM signals are pulses with uniform width, but varying in amplitude (or height). The amplitude of each PAM signal represents the instantaneous amplitude of the analog signal at one point in time.

How often would we need to sample the signal, in order to reproduce it with some degree of fidelity?

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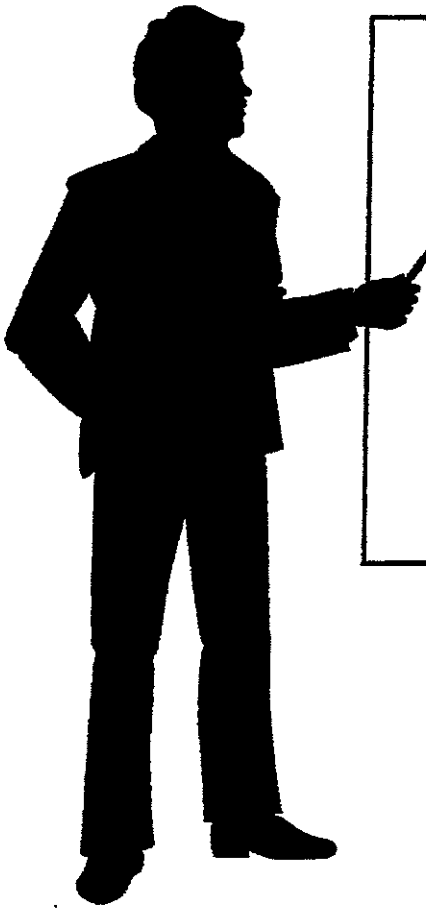
Nyquist Theory



Nyquist Theory

If a band-limited signal is sampled at regular intervals of time and at a rate equal to or higher than twice the highest significant signal frequency, then the samples contain all the information of the original signal. The original signal may be reconstructed by the use of a low-pass filter.

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NYQUIST THEORY

Bell Laboratories had a gentleman named Nyquist who worked on the question of how often to sample the signal. He came up with the Nyquist Theory.

The rate that we sample the analog signal is related to the highest frequency present in the signal.

Theory

The theory says:

> If a band-limited signal is sampled at regular intervals of time and at a rate equal to or higher than twice the highest significant signal frequency, then the samples contain all the information of the original signal. The original signal may be reconstructed by use of a low-pass filter.

Formula

Since we are talking about voice telephone transmission, generally considered to go to 4,000 Hz, we find the following formula:

4000 = Maximum frequency expected from voice

...X2 = Nyquist Theory

8000 = Sampling rate for voice

Sampling

The standard sampling rate for telephone voice-band transmission is 8000 times a second. Theoretically this would limit the voice-band signals to 4000 Hz. (In practice the usable bandwidth is more like 3500 Hz, due to imperfect filter characteristics.)

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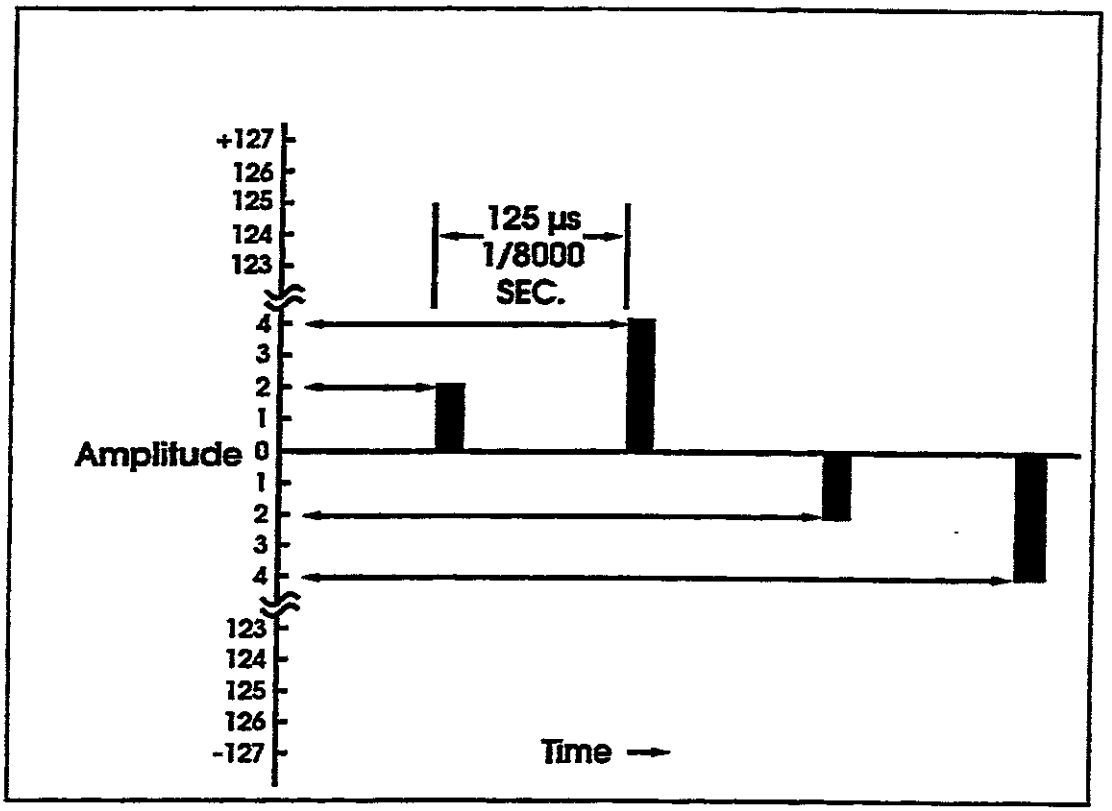
Quantizing



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QUANTIZING

The second step in the conversion process is quantizing.

Measuring

Quantizing essentially matches the PAM signals to a segmented scale. The purpose of quantizing is to "measure" the amplitude (or height) of each PAM signal coming from the sampling process, and assign an integer (whole) number between 0 and ± 127 to define the amplitude of each PAM signal.

In the illustration, the numbers that would be assigned are 2, 4, -2, and -4.

Once the samples have been quantized, they are discarded, having done their function. At this point, the only trace that exists of the human voice being converted is a strand of decimal numbers coming out of the quantizer.

Once a number has been assigned, the next step in the analog-to-digital conversion is encoding.

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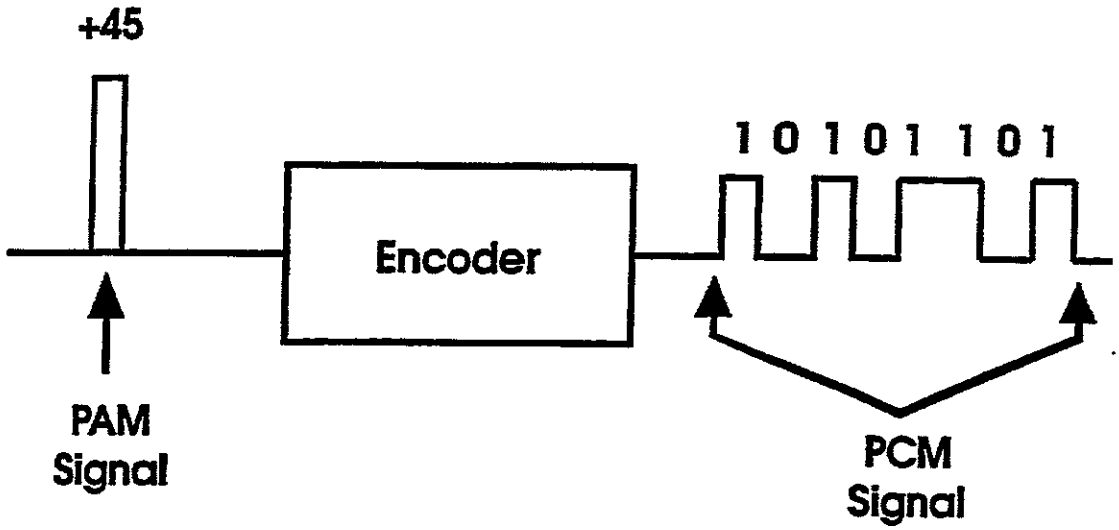
PCM Encoding



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ENCODING

Once the human voice has been sampled and quantized, we need to put it into a binary form. This is done with the encoder.

Encoding

The third step in the process, encoding, involves the conversion of the number that was determined in the quantizing step, to a binary number. Again, a binary form allows the signal to be sent over the telephone line as pulses of electricity.

After it has been quantized, each quantized PAM signal is converted to an 8-bit binary "word," in which each bit may be either a "1" (pulse) or a "0" (no pulse). The 8-bit "word" represents the binary equivalent of the number from the quantizing step.

Example

Let's look at an example. Suppose a PAM signal "measures" +45 on the quantizing scale, as shown in the illustration. The output of the encoding step is the 8-bit "10101101" (i.e., the binary equivalent of +45). As a reminder, you'll practice converting numbers into binary format in Module 2.

Once encoding has been completed, we can send the digitized voice out over the line, representing a 1 (one) with voltage level and a 0 (zero) with ground potential.

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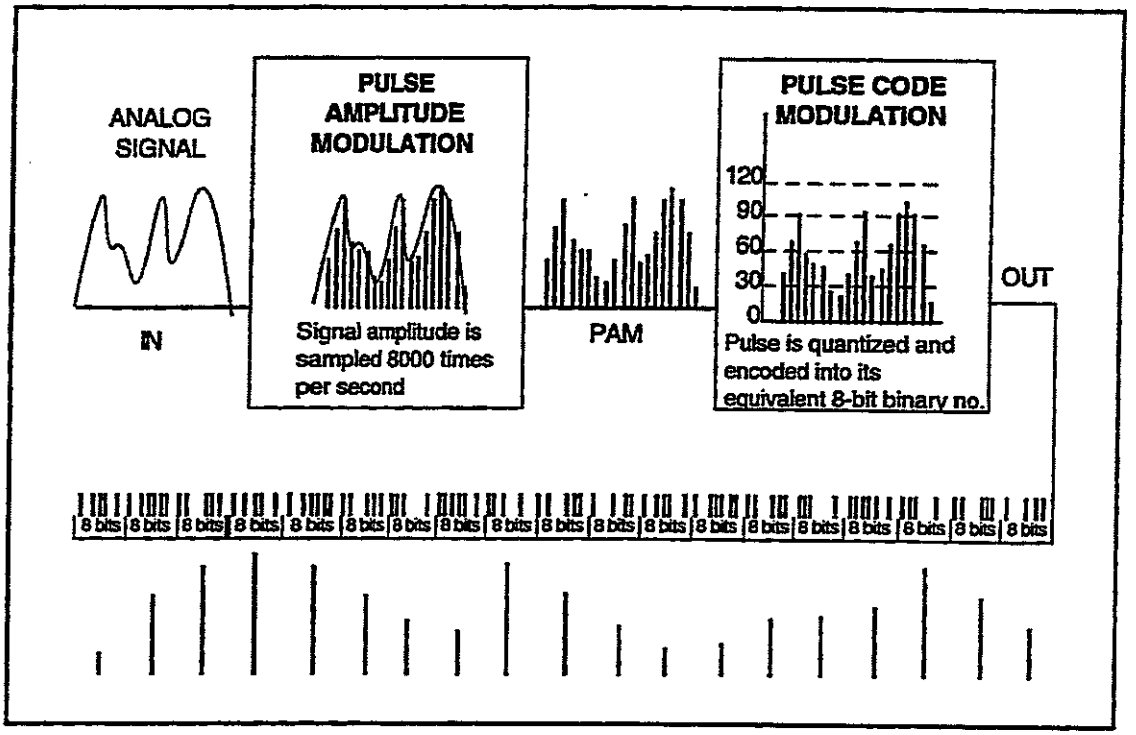
Analog to Digital Conversion



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ANALOG TO DIGITAL CONVERSION - SUMMARY

To summarize, the Analog-to-Digital Conversion essentially involves three steps:

Sampling The analog signal is sampled 8000 times a second. The output of the sampling step is a PAM (Pulse Amplitude Modulation) signal.

Quantizing The PAM signal is matched to a segmented scale. The purpose of this step is to "measure" the amplitude (or height) of the PAM signal and assign an integer number (between 0 and ± 127) that defines that amplitude.

Encoding The integer number is converted to an 8-bit binary number. The output is an 8 bit "word," in which each bit may be either a "1" (pulse) or a "0" (no pulse).

If you are unclear on any of these steps, now is the time to review the material.

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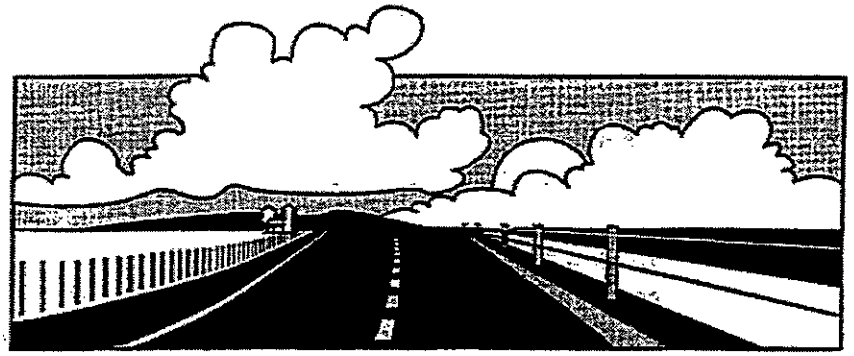

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REVIEW

1) In the sampling step, the analog signal is sampled periodically to determine its instantaneous amplitude at different points in time.

2) Which theory determines the sampling rate for voice signals? d
   a) Theodore N. Vail theory
   b) Watson theory
   c) Casper E. Yost theory
   d) Nyquist theory

3) True or false. In quantizing, the height of the PAM signal is measured to derive a number that represents its amplitude level.
   T

4) Encoding involves the conversion of the number that was determined in the quantizing step into a binary number.

5) The output from the encoding process is: a
   a) 8-bit words
   b) bits
   c) nibbles
   d) PAM signals

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REVIEW - ANSWERS

1) In the sampling step, the analog signal is sampled periodically to determine its instantaneous **value** at different points in time.

2) Which theory determines the sampling rate for voice signals: **d) Nyquist theory**.

3) In quantizing, the height of the PAM signal is measured to derive a number that represents its amplitude level. **True**

4) Encoding involves the conversion of the number that was determined in the quantizing step into a **binary** number.

5) The output from the encoding process is: **a) 8 bit words.**

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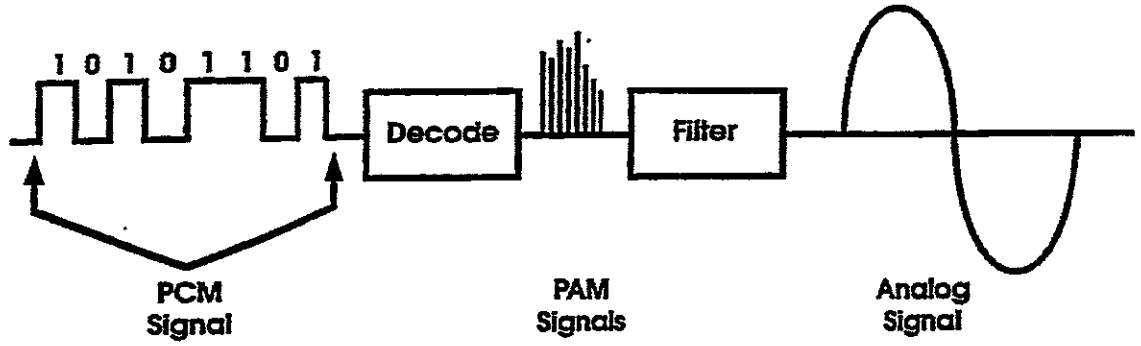
Digital to Analog Conversion



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DIGITAL TO ANALOG CONVERSION

	As the stream of digital bits arrives at the receiving terminal, it must be converted back to an analog waveform in order to be delivered to the listener. The Digital-to-Analog conversion essentially consists of two steps:
Decoding	Step 1 Each received 8-bit "word" is decoded to recover the number that defines the amplitude of each sample (the bit stream is turned into a decimal number). This information is used to rebuild PAM signals of the original amplitudes.
Filtering	Step 2 PAM signals are then passed through a suitably designed filter. When the 8000 PAM signals (per second) are passed through the filter, it reconstructs the original analog waveform.

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Where PCM occurs:

- At Channel Banks
- At Digital Loop Carrier Remote Terminals
- At Customer Provided Equipment

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WHERE DOES PULSE CODE MODULATION OCCUR?

	The conversion from analog to digital and back to analog takes place at different places within our digital network, for example:
	➜ At Channel Banks within the Central Office.
	➜ At Remote Terminals of Digital Loop Carrier systems.
	We will discuss these pieces of equipment later in this module.
	➜ Pulse Code Modulation can also occur on a customer's premises. This takes place in Customer Premises Equipment such as multiplexers or PBXs.

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Error Rate Comparison

Analog	1 per 100,000 Bits
Digital (copper)	1 per 10,000,000 Bits
Digital (fiber)	1 per 1,000,000,000 Bits

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ERROR RATE COMPARISON

	Let's conclude our discussion of digital and analog by looking at error rates.
Average Error Rate	The average error rate in an analog environment is one in 100,000 bits of information. However, in a digital environment, the average error rate is only one in 10,000,000, using copper facilities, and only one in 1,000,000,000 using fiber!
	An error rate of one in 100,000 might sound impressive. But consider this. A conditioned analog private line can usually handle around 9600 bps. One error every 100,000 bits results in an error rate of almost one every ten seconds. This is six errors per minute.
Accuracy	Depending on the type of information being transmitted and the degree of accuracy required, an error rate of one in 100,000 may be totally unacceptable. One error, for example, could mean the difference between a dollar figure being recorded as $100.00 instead of $1,000.00.
	Digital channels significantly improve accuracy and deliver much faster speeds.

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Review

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QUICK SUMMARY

Analog Signal	✔ Continuously varying, always a signal present.
Digital Signal	✔ Only on the line at certain times. When the voltage is present, a 1 is generated; when the voltage is absent, a 0 is generated.
A/D Conversion	✔ Sampled 8000 times a second. ✔ Quantizing into a whole number. ✔ Encoded into a binary number.
D/A Conversion	✔ Decoded back to decimal, producing 8000 PAM samples per second. ✔ The 8000 PAM samples are filtered to produce the original analog signal.
Digital	✔ The major advantage of digital signals is that the signal can be regenerated. At each regenerator, all loss, noise and distortion are controlled. This compares to analog repeater amplifier that merely amplifies the noisy, distorted signal.

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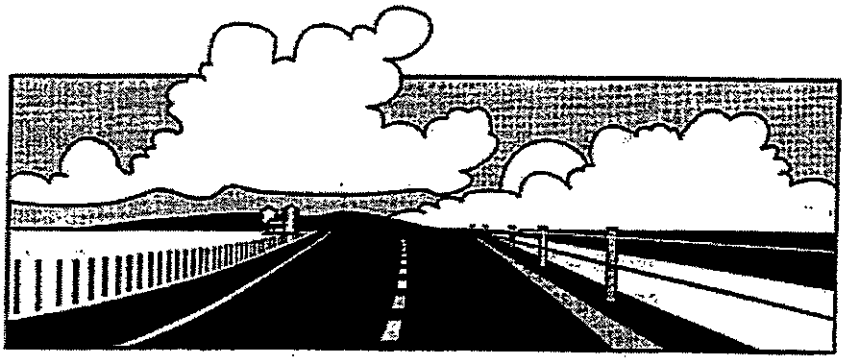

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REVIEW

1) The two steps in the digital-to-analog process are decoding and filtering.

Place an X beside the correct answer(s).

2) Pulse Code Modulation takes place in the following location(s):
   - ✓ At Channel Banks in the Central Office.
   - ___ In Distributing Frame Systems.
   - ✓ In cross-connect terminals.
   - ✓ In Remote Terminals of Digital Loop Carrier systems.
   - ✓ In Customer Premises Equipment.

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REVIEW - ANSWERS

1) The two steps in the digital-to-analog process are decoding and filtering.

2) Pulse Code Modulation takes place in the following location(s):
   X At Channel Banks in the Central Office.
   ____ In Distributing Frame Systems.
   ____ In cross-connect terminals.
   X Remote Terminals of Digital Loop Carrier systems.
   X In Customer Premises Equipment.

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This concludes Part A

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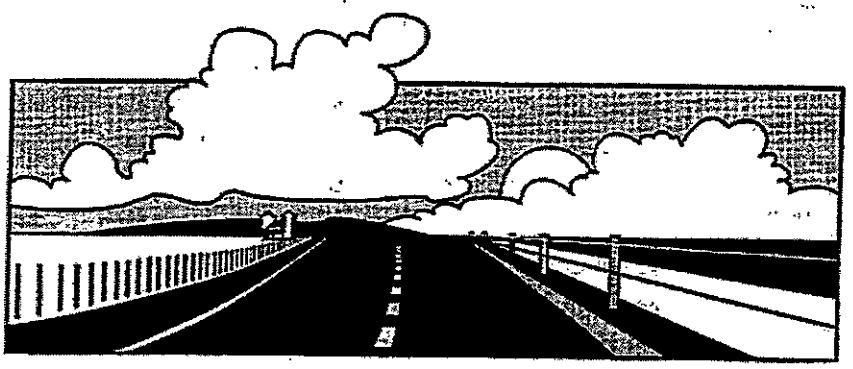

Proceed to Part B

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Table of Contents

PART B: CARRIER SYSTEMS 113
PURPOSE AND PREVIEW 113
Purpose 113
Preview 113
CARRIER SYSTEM 115
Definitions 115
Carrier System 115
Primary Purpose 115
Overview 117
Modulation 117
Multiplexing 117
Demultiplexing 117
SUBSCRIBER LOOP CARRIER 119
Description 119
Purpose 119
INTEROFFICE CARRIER 121
Definition 121
Short Haul 121
Long Haul 121
REVIEW 123
SINGLE CHANNEL PULSE CODE MODULATION 127
Utilization 127
TIME DIVISION MULTIPLEXING 129
Overview 129
Process 131
REVIEW 133
CARRIER TERMS - DIGITAL SIGNAL LEVELS 137
Terms 137
Bit Rates 137
DS0 137
DS1 139
Framing Bits 139
T-CARRIERS 141
T1 141
DS1 vs. T1 141

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T1 Carrier History 143
History 143
Use of T1 143
U S WEST DS1 Service 143
REVIEW 145
T3 Carrier 149
Creating a DS3 149
Framing Bits 149
U S WEST DS3 Service 149
Digital Hierarchy 149
DIGITAL HIERARCHY 151
Standard Speeds 151
DS0 151
DS1 151
DS1C 151
DS2 151
DS3 151
DS4 151
DATA STREAM CONCENTRATION 153
Concentration Levels 153
REVIEW 155
U S WEST DS1 SERVICE 159
DS1 Service 159
Applications 159
BENEFITS OF DS1 SERVICE 161
Error Rates 161
Cost savings 161
Accuracy 161
Fault Isolation 161
Wide Applicability 161
Expandability 161
Service Guarantees 161
Service Description 163
How it Works 163
Applications 163
High Accuracy 165
Fiber quality 165
Multiple Applications 165

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High Capacity 165
24-hour Availability 165
Fault Isolation 165
REVIEW 167
DIGITAL MULTIPLEXERS 171
Application 171
Features 171
DIGITAL FACILITY WITH MULTIPLEXERS 173
Functions 173
Example 173
Channel Bank 173
CHANNEL BANKS 175
Functions 175
Pairs 175
Digroups 175
D4 Channel Bank 177
Modes 177
Plug-in Units 177
Common Units 179
Channel Units 179
REVIEW 181
Functions 185
Types 185
Description 187
Provisioning 187
REVIEW 189
OFFICE REPEATERS 193
Definition 193
Function 193
Location 193
LINE REPEATERS 195
Repeater Spacing 195
SPAN/SPAN LINE/SPAN ACTION 197
Span 197
Span Line 197
Interchangeable Terms 197
Span Section 199

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SYSTEM 201
Extension 201
Identification 201
Numbering 201
REVIEW 203

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PART B: CARRIER SYSTEMS

PURPOSE AND PREVIEW

Purpose

The purpose of this section is to provide an overview of digital carrier systems and the signals that are transported on them. In addition, we will introduce the equipment that makes up the backbone of carrier systems, such as Channel Banks, Office Repeaters and Line Repeaters. T-Carrier is the main digital transport vehicle today. Understanding this technology is vital for effective maintenance of the Central Office.

Preview

Included in this section are the following subjects:

- ☆ Definition of carrier
- ☆ Carrier systems
- ☆ Time Division Multiplexing
- ☆ Digital signal levels
- ☆ T-Carriers
- ☆ Digital hierarchy
- ☆ U S WEST DS1 and DS3 Service
- ☆ Digital multiplexing
- ☆ Channel banks
- ☆ D4 and D5 channel banks
- ☆ Office, line repeaters
- ☆ Spans, span lines, and span sections

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Carrier:

- ☆ Two different meanings
- ☆ Our focus: a system that transports multiple channels over a common facility
- ☆ Primary benefit is efficiency
- ☆ Analog and digital carriers

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CARRIER SYSTEM

The name, "carrier," is subject to some confusion in the world of telecommunications, because the term has two different meanings and because both meanings are used frequently.

Definitions

A carrier is:

- ★ A company that provides telecommunications services, such as an Interexchange Carrier (AT&T or Sprint, for example).
- ★ A system that transports multiple channels or signals over a common transmission medium, such as a Subscriber Loop Carrier.

Carrier System

We will now learn about the second definition. To help differentiate between the two, think of it as a carrier system. It is a system because, as you will see, it uses components and processes to transport signals.

Primary Purpose

The primary purpose, and benefit, of a carrier system is efficiency. Because carrier systems use common facilities, they are more economical and, in addition, allow a quicker response to service needs, either in repair or in construction.

For example, a T-Carrier system delivers 24 conversations over only 2 pair of wires, one pair for each direction.

There are two types of carrier systems: analog and digital. As digital is clearly the wave of the future, that is what we will concentrate on in this section.

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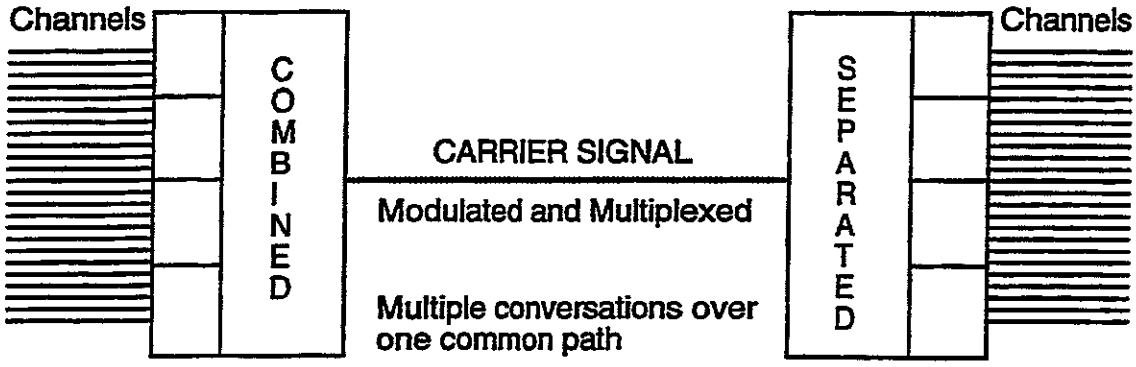
Carrier System



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CARRIER SYSTEM, (continued)

Overview

Carrier systems are composed of a device (such as a Channel Bank or a terminal) at each end of the system, interconnected with a high or low speed transmission line. High speed transmission can be defined as a bit rate of 44.736 Mbps (DS3 level) and low speed at a bit rate of 1.544 Mbps (DS1 level). The function of a Channel Bank or terminal is to modulate and multiplex individual conversations for simultaneous transmission over a high speed line, as shown in the illustration.

Modulation

To modulate a signal (a conversation) means to process it or change it into another form which is suitable for transmission over the telephone line. The signal must also be demodulated by the receiving Channel Bank, back to its original form.

Multiplexing

Multiplexing is a process whereby a number of individual channels are combined into a common spectrum, or a common bit stream, for transmission.

Demultiplexing

Demultiplexing is the separation of the common spectrum, or bit stream, into individual channels.

Two examples of carrier systems are:

- Subscriber Loop Carrier
- Interoffice Carrier

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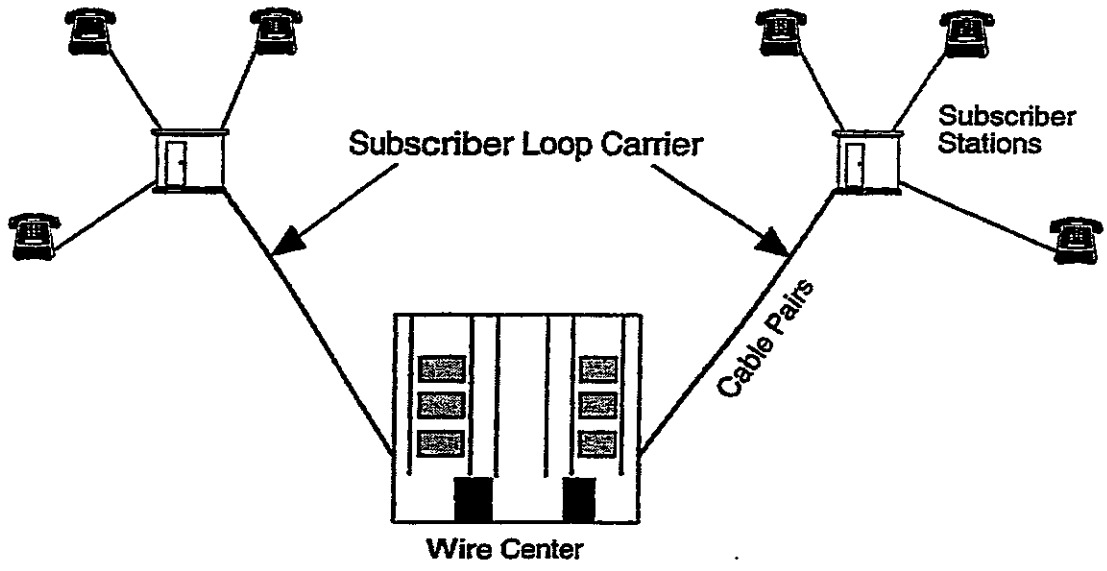
Subscriber Loop Carrier



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SUBSCRIBER LOOP CARRIER

Description

Subscriber Loop Carrier facilities are carrier systems which provide connections for Central Offices to subscriber locations.

Purpose

Subscriber Loop Carrier optimizes the utilization of loop cable facilities by carrying multiple subscribers on a few cable pairs, as illustrated. We'll look at the capabilities of some specific Subscriber Loop Carrier systems in Module 1, Book II. Subscriber Loop Carrier is also referred to as a pair gain system or as Digital Loop Carrier.

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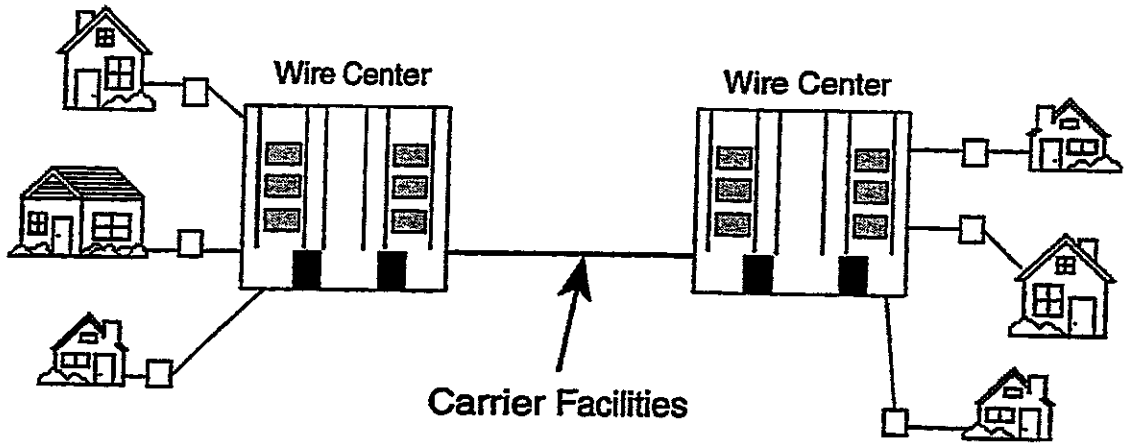
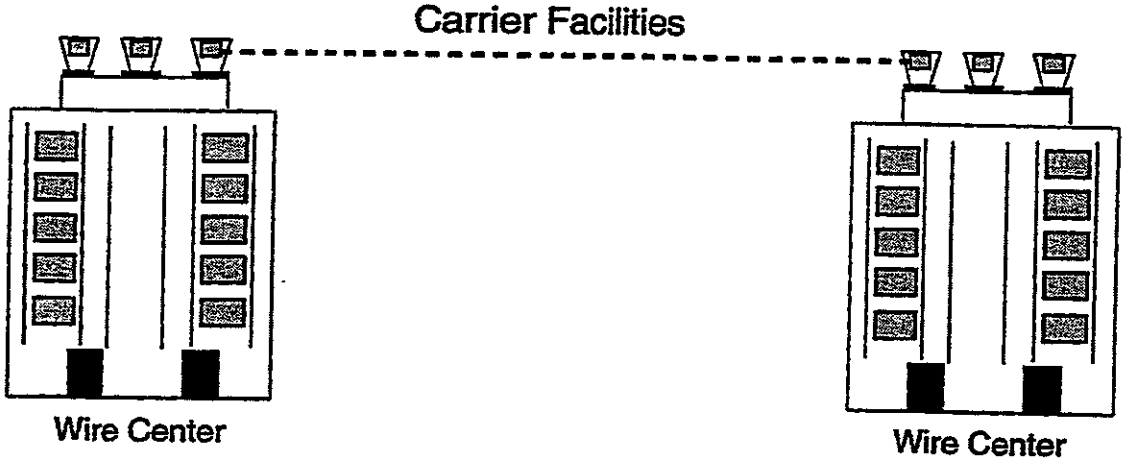
Interoffice Carrier (Short Haul)



Interoffice Carrier (Long Haul)



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INTEROFFICE CARRIER

Definition

Interoffice Carrier facilities are carrier systems which are dedicated to the interconnection of Wire Centers. Interoffice Carrier is divided into two categories: short haul and long haul carrier.

Short Haul

Short haul carrier provides connections up to 250 miles, between telephone company Wire Centers.

Long Haul

Long haul carrier provides connections up to 4,000 miles, between telephone company Wire Centers.

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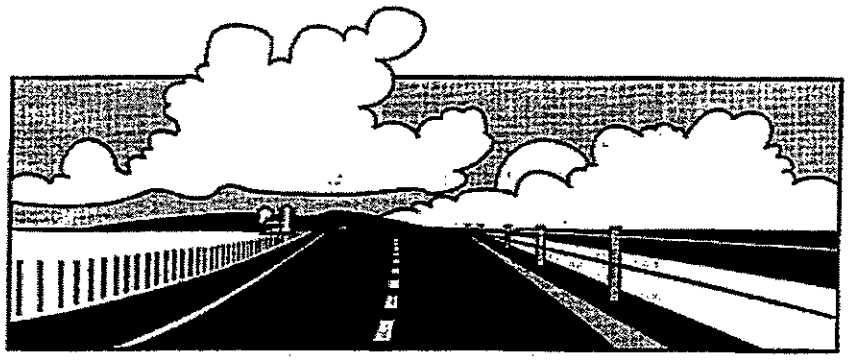

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REVIEW

1) A carrier system transports multiple channels or signals over a common facility.

2) The primary benefit of a carrier system is efficiency.

3) The process where a number of individual channels are combined into a common bit stream for transmission is called: d

   a) Modulation
   b) Demultiplexing
   c) PCM
   d) Multiplexing

4) Match the term with the correct explanation.

   Interoffice carrier b — a) Carrier systems that provide connections from Central Offices to subscriber locations.

   Subscriber Loop Carrier a — b) Carrier systems which are dedicated to the interconnection of Wire Centers.

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REVIEW - ANSWERS

1) A carrier system transports **multiple** channels or signals over a **common** facility.

2) The primary benefit of a carrier system is **efficiency**.

3) The process where a number of individual channels are combined into a common bit stream for transmission is called: **d) Multiplexing**

4) Interoffice carrier: **(b)**
Subscriber Loop Carrier: **(a)**

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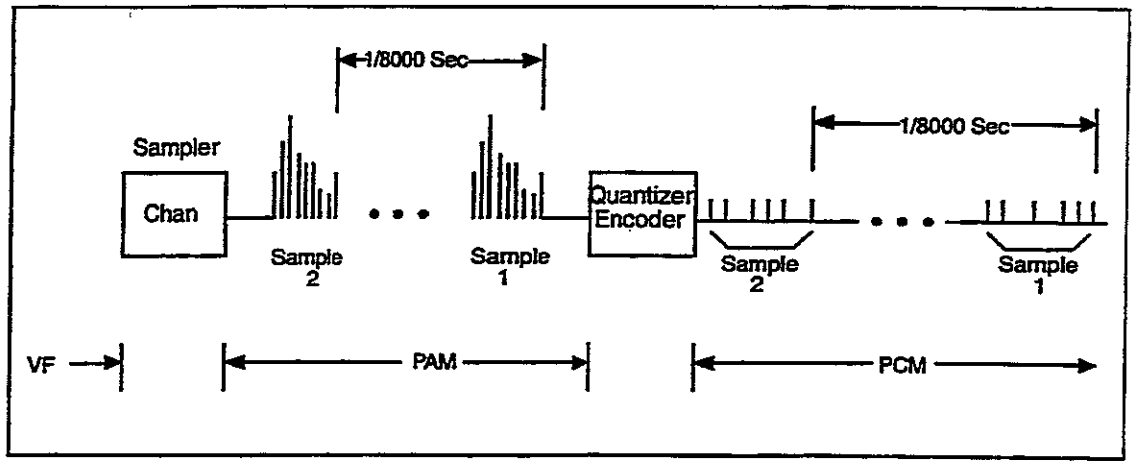
Single Channel PCM



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SINGLE CHANNEL PULSE CODE MODULATION

Previously, we discussed the analog-to digital conversion for a single voice channel or circuit.

If the analog signal is sampled 8000 times a second, there would be 8000 signals per second or 1/8000 seconds (or 125 microseconds) apart, as shown in the illustration.

Utilization

If we transmitted the single channel PCM signal down the transmission line, there would be a considerable amount of time between samples when the line would not be "used."

It figures out to about 4% line utilization - not too efficient!

This is where Time Division Multiplexing comes in.

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Time Division Multiplexing

Time Division Multiplexing:

- The A/D conversion process is so rapid that any transmission with a single channel would sit idle for 120 microseconds
- TDM uses this idle time to multiplex 24 channels into 24 time slots for transmission over a single facility
- TDM's primary benefit is efficiency

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TIME DIVISION MULTIPLEXING

Overview

In the analog to digital (A/D) conversion process, a single channel 8-bit word is generated every 125 microseconds. Encoding a sample into a complete PCM word takes about 5.2 microseconds. The process is so rapid that any transmission fed by a single PCM channel would be idle for about 120 microseconds between samples.

Time Division Multiplexing takes advantage of this unused time between samples of a single channel or circuit. Time Division Multiplexing, or TDM, places 24 single channel digital signals into 24 discrete time slots. These 24 time slots (channels or conversations) are transmitted over a common line.

The primary benefit, and reason to use Time Division Multiplexing, is efficiency.

Other reasons include:

- Simplification
- Economy

Time Division Multiplexing is the multiplexing method most often used today. It can take place in telco facilities, such as in Channel Banks located in Central Offices, or on a customer's premises, in a digital terminal, as part of a PBX or as a separate unit in a company's telecommunications network.

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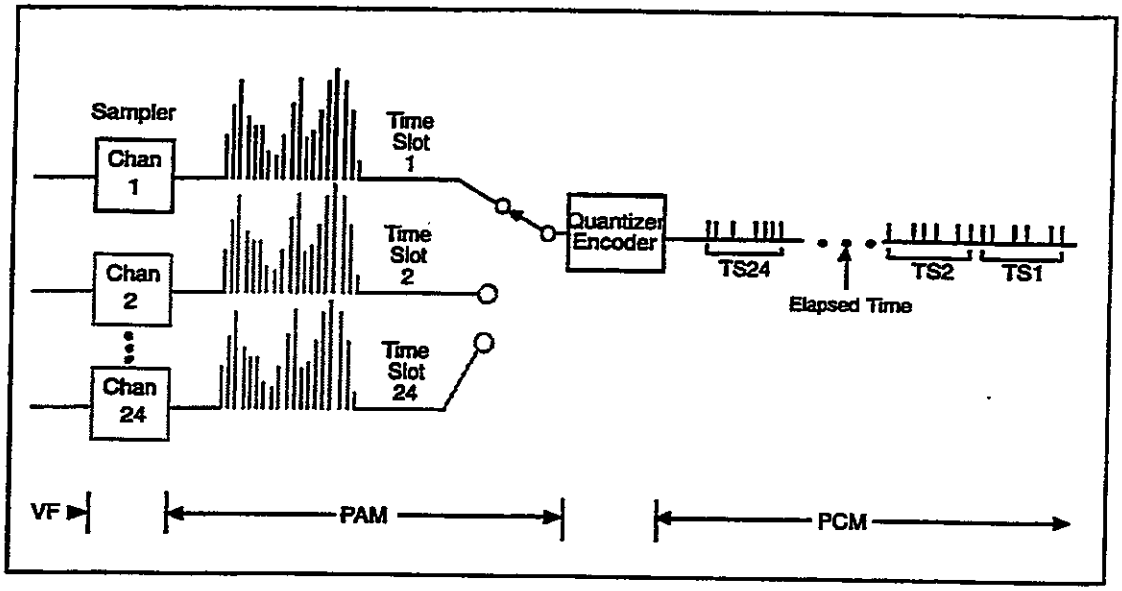
Time Division Multiplexing



KEY: TS = Time Slot

- TDM divides the signal into 24 time slots
- Conversion process repeated 8,000 times a second
- Converted back to analog at other end

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TIME DIVISION MULTIPLEXING, continued

Process

The coded sample from channel one is placed in time slot number one, the coded sample from channel two is placed in time slot number two, and so on, until all 24 channels have been sampled, as shown in the illustration. [redacted] pass of [redacted] each frame consists of 24 samples placed on 24 time slots.

The 24 channels (time slots or conversations) are sampled sequentially. Each PAM signal is passed, in its turn, to a common quantizer/encoder circuit. As each PAM signal is encoded, an 8-bit word is transmitted.

This procedure occurs for all 24 channels, 8000 times per second.

After each of the 24 conversations are sampled, quantized, coded, and placed in separate time slots, they are transmitted over a common communications path to the demultiplexer at the receiving location.

The demultiplexer receives the digitally coded samples and places the sample from time slot one on channel number one, the sample from time slot two on channel number two, and so forth. The digital sample is then converted back into an analog signal. Since each conversation is separated by time, this is why the technique is called Time Division Multiplexing.

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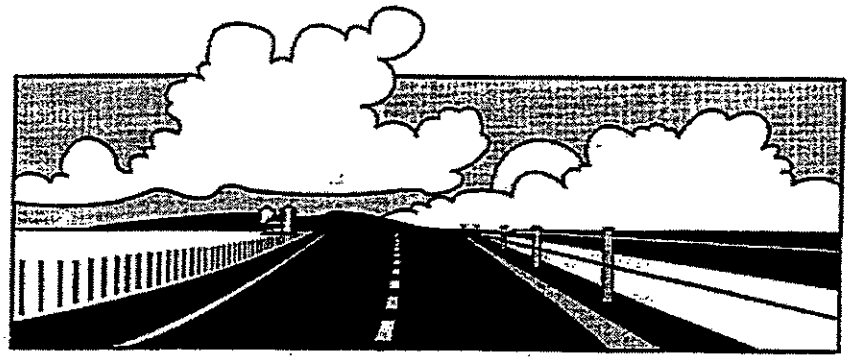

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REVIEW

1) Time Division Multiplexing takes advantage of the _____idle_____ time between samples of a single channel or circuit.

Fill in the blank with the appropriate number.

2) TDM places 24 single channel digital signals into _____24_____ discrete time slots.

3) A complete pass of all sampled channels is called a(n) _____frame_____.

4) After each channel has been sampled sequentially, the PAM signals are passed to the _____encoding_____ circuit.

5) The digitally coded samples are placed into their correct time slots at the receiving end by the _____demultiplexer_____.

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REVIEW - ANSWERS

1) Time Division Multiplexing takes advantage of the **unused** time between samples of a single channel or circuit.

2) TDM places 24 single channel digital signals into **24** discrete time slots.

3) A complete pass of all sampled channels is called a **frame**.

4) After each channel has been sampled sequentially, the PAM signals are passed to the **quantizer/encoder** circuit.

5) The digitally coded samples are placed into their correct time slots at the receiving end by the **demultiplexer**.

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Carrier Terms

Digital Signal Levels:

- The basic digital signal building block is DS0
- DS0 transmits at 64 kbps:

  8 Bit words
  X8000 times per second
  = 64,000 bits per second or 64 kbps.

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CARRIER TERMS - DIGITAL SIGNAL LEVELS

Terms

To oversimplify the process, a carrier signal is built by combining digitized voices into one bit stream and transmitting them on a four wire span line, then putting them back in the right places at the other end.

Let's define some of the terms that are used.

Bit Rates

The bit rate is the rate at which we are able to send binary information through a system. This is not how fast the bit travels, but rather how many bits we can send into the system each second.

Digital data transmission is measured in bits per second (abbreviated as bps or b/s):

Kilobits per second = kbps or kb/s = 1,000 bits per second

Megabits per second = Mbps or Mb/s = 1,000,000 bits per second.

Gigabits per second = Gbps or Gb/s = 1,000,000,000 bits per second.

DS0

The basic "building block" of digital transmission is DS0, or one channel. This channel transmits eight bit binary words 8000 times per second.

Digital Signal Zero (DS0):

8 Bit words
X 8000 times per second
= 64000 bits per second or 64 kbps, per channel

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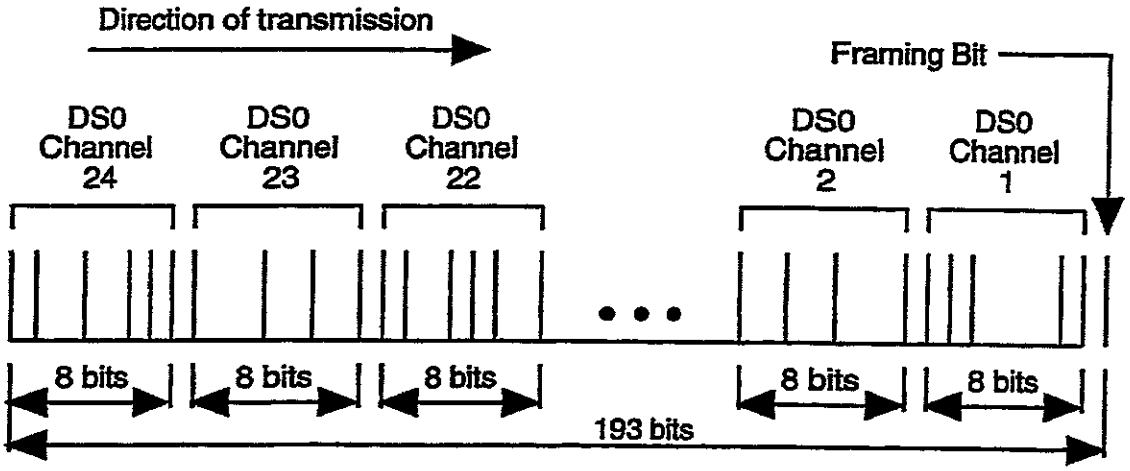
Digital Signal Level
Creating a DS1



DS1 Frame

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DIGITAL SIGNAL LEVELS, continued

DS1

Digital Signal One (DS1) is the digital transmission standard. As shown on the illustration, DS1 takes 24 DS0 signals and multiplexes them together, adding one framing bit for each 24 channel frame. (Remember, a complete pass of all sampled channels is called a frame.)

Digital Signal One (DS1):

64,000	bits per second, per channel (DS0)
X 24	channels
= 1,536,000	bits per second
1,536,000	bits per second
+ 8,000	framing bits per second
= 1,544,000	bits per second or 1.544 Mbps (DS1-level signal)

Framing Bits

Framing bits are used to maintain synchronization between the sending unit and the receiving unit. In other words, framing bits ensure that channel one is talking to channel one, channel two is talking to channel two, etc.

3 24 8/192

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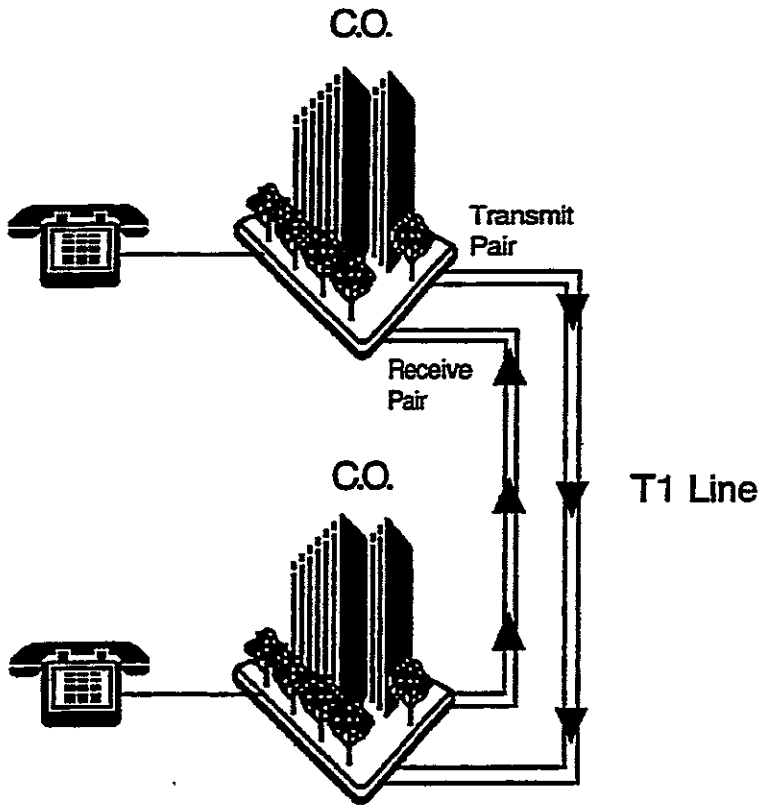
T1 Carrier



- ✔ Two-way digital carrier
- ✔ Supports 24 channels at 1.544 Mbps
- ✔ Uses DS1 signal level

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T-CARRIERS

T1

A commonly used carrier system, T1 Carrier, is a two-way, digital carrier that supports 24 DS0 channels and operates at 1.544 Mbps.

The transportation medium is often copper cable pairs. T-Carrier systems are Time Division Multiplexed transmission facilities.

A T1 delivers 24 conversations over only 2 pairs of wires, one pair for each direction (transmit and receive).

DS1 vs. T1

DS1 circuits "ride on" T1 Carrier; T1 Carrier uses the DS1 signal level.

While you will commonly hear DS1 and T1 used interchangeably, there is a distinction.

The term, "DS1," refers to the digital level or signal, while the term, "T1," refers to the actual transportation system.

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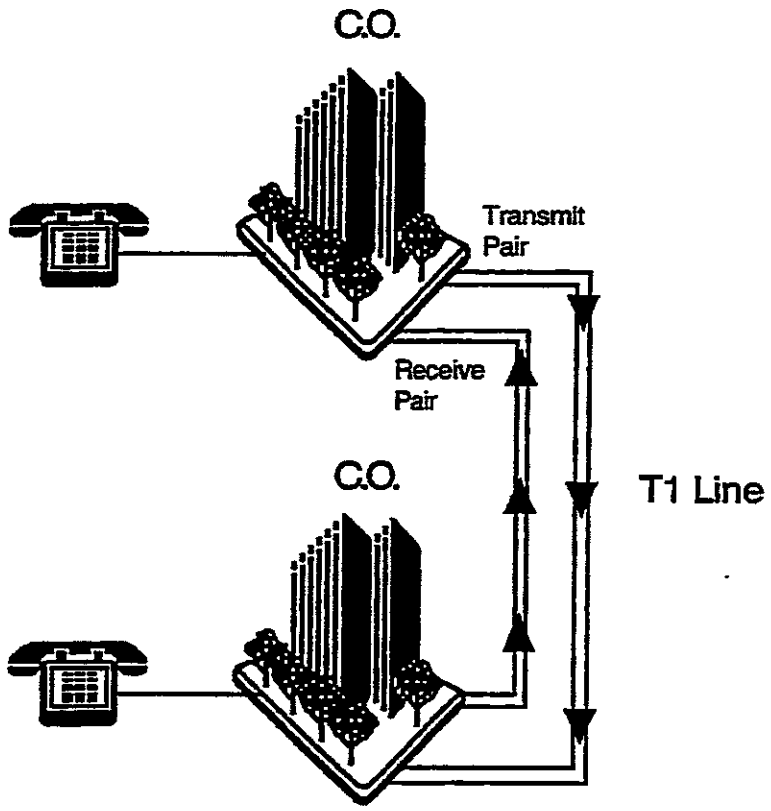
T1 Carrier History



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T1 CARRIER HISTORY

History

Telephone companies originally used T1s as carrier systems between Central Offices.

When the service was repriced in the 1980s, larger companies who were telephone company subscribers began purchasing DS1-level circuits for their own telecommunications use.

Users range from large manufacturing companies using DS1 for voice and data transmission, to cellular carriers, who use DS1 circuits as part of their cellular network, connecting remote cell sites that receive mobile signals, to the cellular carrier's switching offices.

Use of T1

T-Carrier systems are frequently used to provide interoffice trunking where the distance is about 50 miles or less. They are also used to provide high capacity digital services directly to the customer.

U S WEST DS1 Service

U S WEST DS1 Service is actually a product we offer to customers, enabling the transmission of voice, data and video signals. We'll discuss it shortly.

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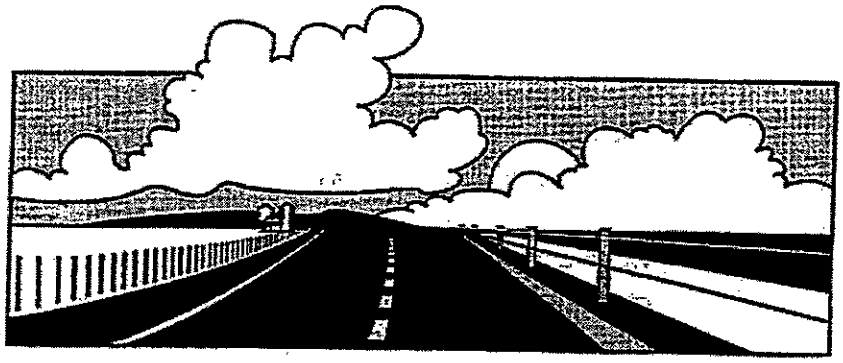

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REVIEW

1) True or false. The bit rate measures how many bits can be transmitted in the system, each second. true

2) 1 megabit is equal to 1,000,000 bits.

3) The building block of digital transmission is DS0.

4) Demonstrate how a DS1 signal is created, showing rates.
24 channels are encoded 8000 times per sec, each one quantized and encoded, then placed in a time slot relative to the channel being encoded.

5) framing bits are used to maintain synchronization between the sending unit and the receiving unit.

Place an X beside the statements that apply.

6) Indicate which statements apply to T1 Carrier.
___ Needs only 2 wires
✓ Supports 24-64 kbps channels
✓ Often operates over copper cable
✓ Frequently provides central office trunking
___ One-way carrier system

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REVIEW - ANSWERS

1) The bit rate measures how many bits can be transmitted in the system, each second. **True**

2) 1 megabit is equal to **1,000,000 bits**.

3) The building block of digital transmission is **DS0**.

4) A DS1 signal is created as follows:

64,000	**bits per second (DS0 rate)**
X 24	**channels**
= 1,536,000	**bits per second**
1,536,000	**bits per second**
+ 8,000	**framing bits**
= 1,544,000	**bits per second or 1.544 Mbps (DS1-level signal)**

5) **Framing** bits are used to maintain synchronization between the sending unit and the receiving unit.

6) Indicate which statements apply to T1 Carrier.
   ____ Needs only 2 wires
   X Supports 24 64 kbps channels
   X Often operates over copper cable
   X Frequently provides interoffice trunking
   ____ One-way carrier system

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Higher Level Carriers

T3 Carrier:

- Supports DS3
- Operates at 44.736
- Used to transport large volumes of data, video and voice traffic
- Steps:
  - 4 DS1s multiplexed together to form a DS2
  - 7 DS2s multiplexed together to form a DS3

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T-CARRIERS, continued

T3 Carrier

T3 Carrier supports a Digital Signal level 3, or DS3. DS3 is attained by multiplexing DS2-level circuits together. DS3 operates at 44.736 Mbps. DS3 circuits are used to transport large volumes of data, video and voice traffic, usually over fiber optic lines.

Creating a DS3

Creating a DS3 takes two steps.

Digital Signal Level 3 (DS3):

1. Four DS2 circuits are multiplexed to form a DS3 circuit. The DS2 (T2 Carrier) level is the equivalent of 96 voice channels.
2. Seven DS2 circuits are multiplexed together to form one DS3, which has 672 voice channels. A single DS3 circuit is the equivalent of 28 DS1s.

Framing Bits

Addition of framing bits creates the total DS3 bit rate of 44.736 Mbps.

U S WEST DS3 Service

U S WEST DS3 Service is a product offering for data, voice, imaging and video applications; we'll cover it momentarily.

Digital Hierarchy

Next we summarize the different digital signal levels. They form a digital hierarchy known as the North American Digital Hierarchy.

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North American Digital Hierarchy

Signal Rate	# of Channels	# of DS1s	Bit Rate	Other Names
DS0	1	-	64 kbps	DDS
DS1	24	1	1.544 Mbps	T1, Hicap
DS1C	48	2	3.152 Mbps	T1C
DS2	96	4	6.312 Mbps	T2
DS3	672	28	44.736 Mbps	T3, 45 Mb
DS3C	1344	56	90.52 Mbps	
DS4	4032	168	274.176 Mbps	T4

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DIGITAL HIERARCHY

Standard Speeds

Standards for digital transmission speeds are necessary to enable digital transport, interface and production of equipment to take place. There are two standards worldwide. Shown is the North American Digital Hierarchy, used in the U.S., Canada and Japan. The rest of the world uses the European Digital Hierarchy. They are ***not*** compatible with each other.

DS0

DS0 is the first level of the digital hierarchy. DS0 operates at 64 kbps on one channel time slot.

DS1

DS1 operates at 1.544 Mbps. DS1 is 24 channels or time slots. The DS1 level consists of 24 DS0 level signals plus a framing bit added after each repetition of 24 eight bit words.

DS1C

DS1C operates at 3.152 Mbps. DS1C is 48 DS0-level channels. DS1C is two DS1 level signals multiplexed into a single digital output.

DS2

A DS2's speed is 6.312 Mbps. DS2 is 96 DS0-level channels. DS2 is four DS1-level signals multiplexed into a single digital output. DS2 is used as an intermediate step between DS1 and DS3-level signal processing multiplexers.

DS3

DS3 is 672 DS0-level channels. DS3 is 28 DS1-level signals multiplexed into a single digital output.

DS4

DS4 is 4032 DS0-level channels. DS4 is 168 DS1-level signals multiplexed into a single digital output.

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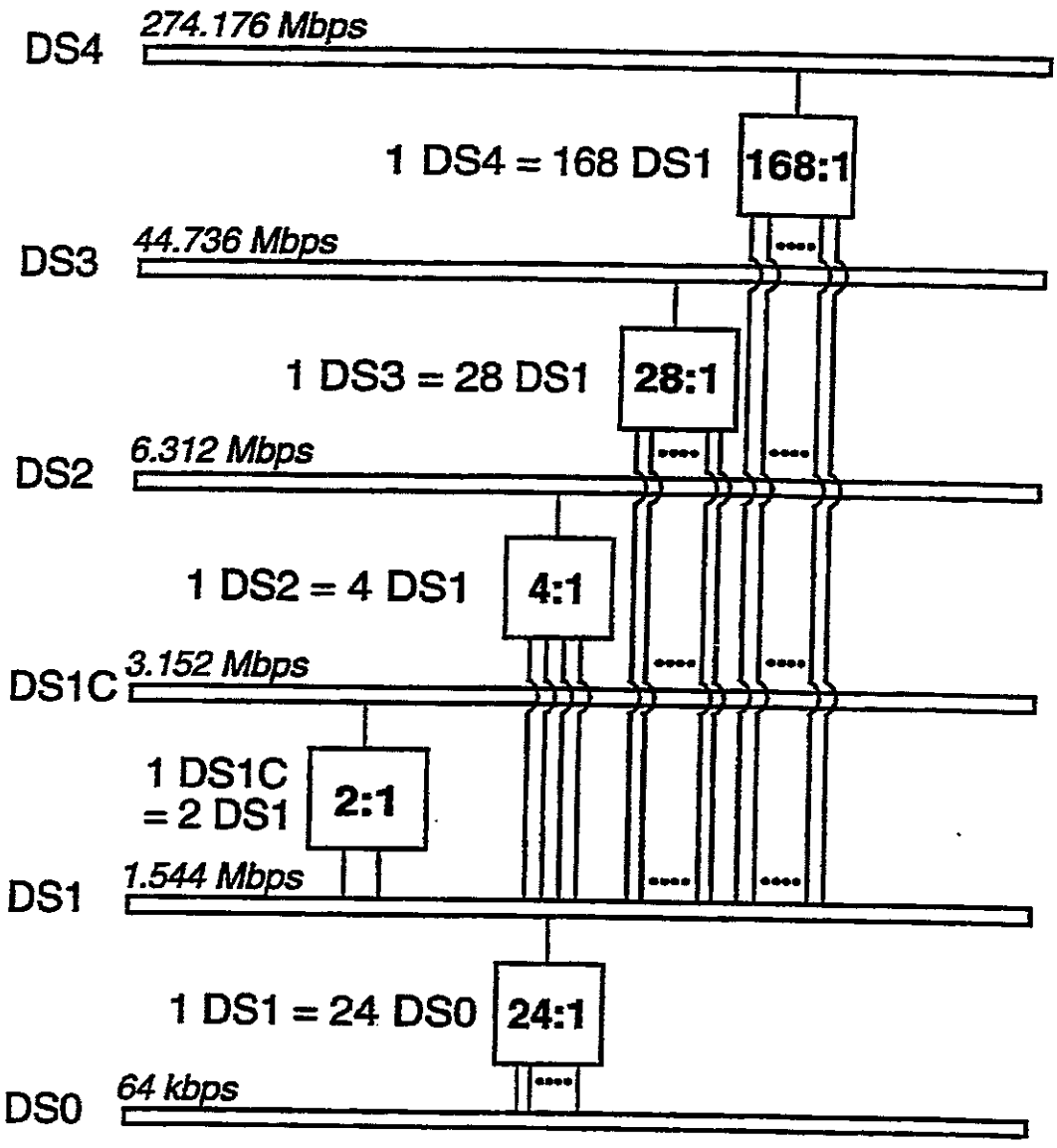
Data Stream Concentration



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DATA STREAM CONCENTRATION

Concentration Levels

The illustration further shows how the data stream is concentrated, as you move higher in the digital hierarchy.

Note the following concentration levels on the illustration:

- ★ 1 DS1 is 24 DS0 channels multiplexed together
- ★ 1 DS1C is 2 DS1-level signals multiplexed together
- ★ 1 DS2 is 4 DS1-level signals multiplexed together
- ★ 1 DS3 is 28 DS1-level signals multiplexed together
- ★ 1 DS4 is 168 DS1-level signals multiplexed together

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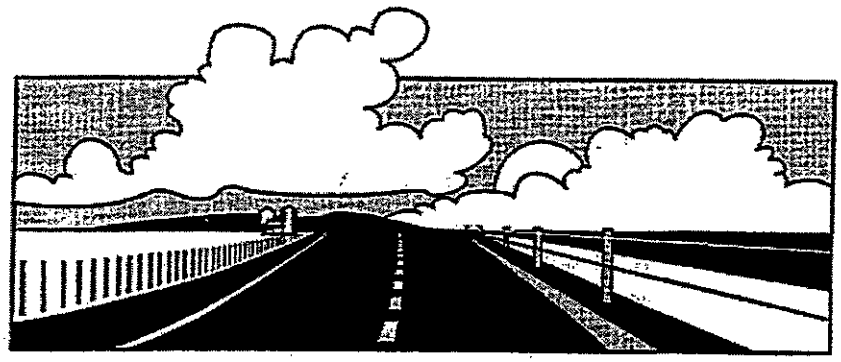

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REVIEW

1) DS3 operates at a bit rate of 44.736 Mbps.
   44.736 Mbps
   6.312 Mbps
   44.736 Gbps
   90.52 Mbps

2) List the two steps necessary to create Digital Signal Three (DS3):
   1) Max 4 DS1s into a DS2.
   2) Max 7 DS2s into a DS3

3) Complete the chart below by filling in the blank spaces.

Signal Rate	# of Channels	# of DS1s
DS0		0
DS1		1
DS2		4
DS3		28

4) DS2 is used as a(n) intermediate step between DS1 and DS3 signal processing multiplexers.

+96 1/672

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REVIEW - ANSWERS

1) DS3 operates at a bit rate of **44.736 Mbps**.

2) List the two steps necessary to create Digital Signal Three:
   1) **Four DS1-level circuits are multiplexed together to form a DS2 circuit.**
   2) **Seven DS2 circuits are multiplexed together to form one DS3.**

3)

Signal Rate	# of Channels	# of DS1s
DS0	**1**	**-**
DS1	**24**	**1**
DS2	**96**	**4**
DS3	**672**	**28**

4) DS2 is used as an **intermediate** step between DS1 and DS3 signal processing multiplexers.

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U S WEST Service Offering DS1

U S WEST DS1 Service:

- Offers a cost-effective, high-volume, point-to-point, intraLATA communications service
- Two-way digital transmission at 1.544 Mbps
- May be multiplexed and demultiplexed by the customer
- Supports a broad range of customer applications

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U S WEST DS1 SERVICE

We've mentioned that U S WEST offers the benefits of high-speed digital transmission to its customers. Let's examine two of its products - U S WEST DS1 and DS3 Service.

DS1 Service Description

U S WEST DS1 Service is comprised of dedicated data, voice, or video lines transmitting in the digital signaling format at 1.544 Mbps. This is a cost-effective, high-volume, point-to-point, intraLATA communications service. This high capacity line may be multiplexed and demultiplexed by the customer and be broken down into several voice and data communication channels.

Applications

Examples of customer applications include:

Integration of voice, data and video onto a single facility.

Video conferencing.

Terminal-to-host computer communications.

High volume transaction-based applications, such as billing, reservations, customer service, or database access.

Batch data transfer, such as payroll and inventory.

Communication links between cellular telephone cell sites and cellular carrier switching offices.

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Benefits of DS1 Service

Benefits include:

- ✔ Extremely low error rate
- ✔ Cost savings
- ✔ Accuracy
- ✔ Fault isolation
- ✔ Wide applicability
- ✔ Expandability
- ✔ Service guarantees

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BENEFITS OF DS1 SERVICE

The benefits of DS1 service include:

Error Rates — Digital DS1 service delivers a bit error rate of one in ten million.

Cost savings — By merging multiple private lines onto one high speed digital link, customers can save considerable installation, equipment and maintenance expenses.

Accuracy — As digital links, DS1s are less prone to errors than analog lines.

Fault Isolation — Consolidating multiple applications onto a single DS1 permits monitoring of only one circuit instead of many separate ones. Enhanced link diagnostics are available with DS1 service.

Wide Applicability — DS1s can support a broad range of applications.

Expandability — A customer's usage may cost-justify a DS1 link without requiring its full capacity.

Service Guarantees — U S WEST is introducing provisioning and repair guarantees for DS1 and DS3 service agreements.

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U S WEST Service Offering DS3

U S WEST DS3 Service:

- DS3 circuits transmit at 44.736 Mbps; its capacity is equal to 672 DS0 channels
- Dedicated, digital, point-to-point connections
- High standards of accuracy and availability
- Usually provided on fiber facilities
- Multiple applications

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U S WEST DS3 SERVICE

Service Description

DS3 circuits have a bandwidth of 44.736 Mbps. Its capacity is equal to 672 DS0 channels of 64 kbps each, or 28 DS1 circuits. DS3 is sometimes referred to as T3 or 45 megabit service.

DS3s provide dedicated digital, point-to-point connections between customer-designated premises and U S WEST Serving Central Offices.

How it Works

Multiple DS1 channels are reduced to one signal stream through a DS3 multiplexer on the customer's premises. The DS3 signal is then transmitted over a permanent line to the destination site.

Applications

Examples of applications include:

- Bulk data and consolidated data/voice/video traffic.
- Broadcast quality video.
- Large corporate/government networks requiring multiple DS1 capacity for data, voice, imaging and video applications.

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Benefits of DS3 Service:

Benefits include:

- ✔ High accuracy
- ✔ Fiber quality
- ✔ Multiple applications
- ✔ High capacity
- ✔ 24-hour-a-day availability
- ✔ Faster fault isolation

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BENEFITS OF DS3 SERVICE

The benefits of DS3 service include:

High Accuracy — DS3 service achieves very high standards of accuracy. Because DS3 service typically uses fiber facilities, error rates are extremely low.

Fiber quality — Fiber facilities offer a higher level of performance in areas such as signal quality and security.

Multiple Applications — Voice, data, or video signals can be carried on the same facility.

High Capacity — Multiple DS1 circuits can be combined onto a DS3 circuit, allowing very high-speed applications such as broadcast quality video.

24-hour Availability — The DS3 line is available 24 hours a day.

Fault Isolation — Faster fault isolation - instead of monitoring multiple circuits, only one circuit has to be monitored.

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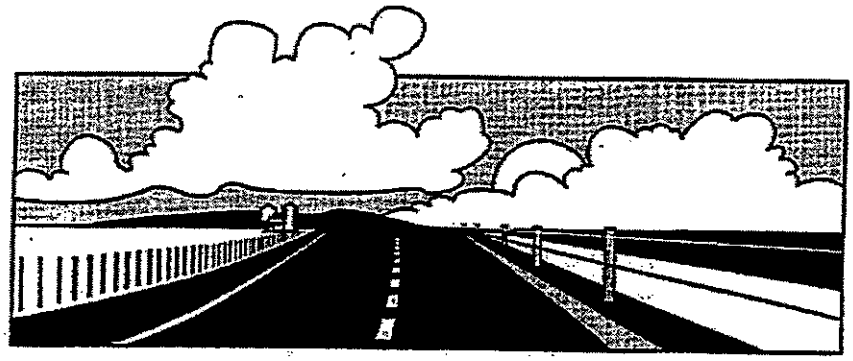

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REVIEW

1) U S WEST DS1 service may be mixed and demixed by the customer.

2) List at least two applications that U S WEST DS1 service could be used for.

voice, video

3) List at least two benefits of U S WEST DS3 service.

fiber, high capacity

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REVIEW - ANSWERS

1) U S WEST DS1 service may be **multiplexed** and **demultiplexed** by the customer.

2) Any two of the following answers are acceptable: **Automatic Teller machines; integrated voice, data and video; video conferencing; terminal-to-host computer communications; high volume transactions-type applications, such as billing, reservations, customer service, or database access; batch data transfer, such as payroll and inventory.**

3) Any two of the following answers are acceptable: **High accuracy and availability; fiber quality; multiple applications; high capacity; 24-hour availability; faster fault isolation.**

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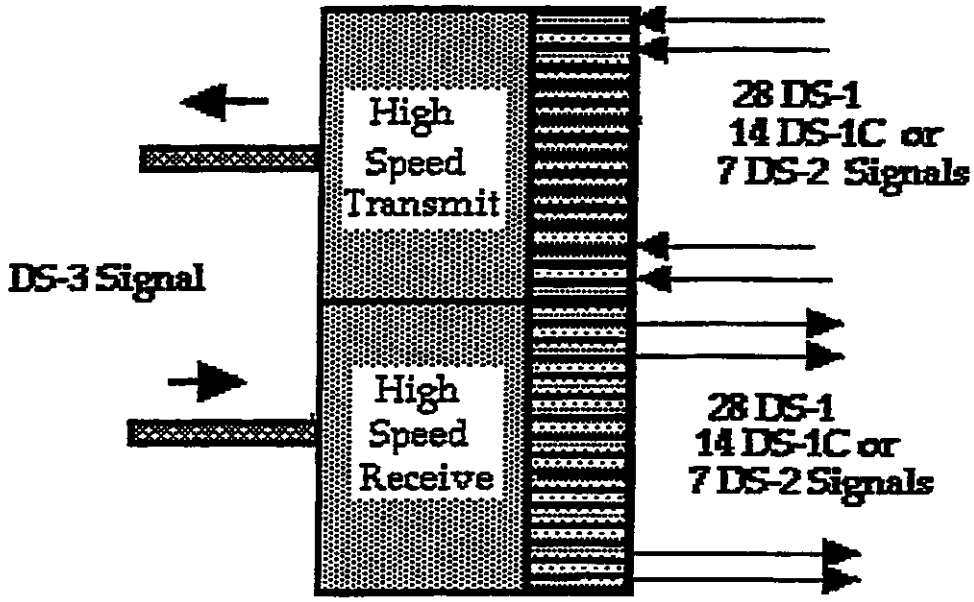
Digital Multiplexer



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DIGITAL MULTIPLEXERS

Application

A digital multiplexer combines and translates signals from one digital level to another.

It provides an interface between the different bit rates in the network; it accepts multiple lower-speed signals on one side and delivers a single high speed signal on the other side.

As we have stated, at the other end of the transmission system a demultiplexer is needed to separate the single higher bit stream into multiple lower rate bit streams.

Features

In addition, multiplexing equipment generally provides features such as:

- Failure detection
- Alarms
- Protection switching

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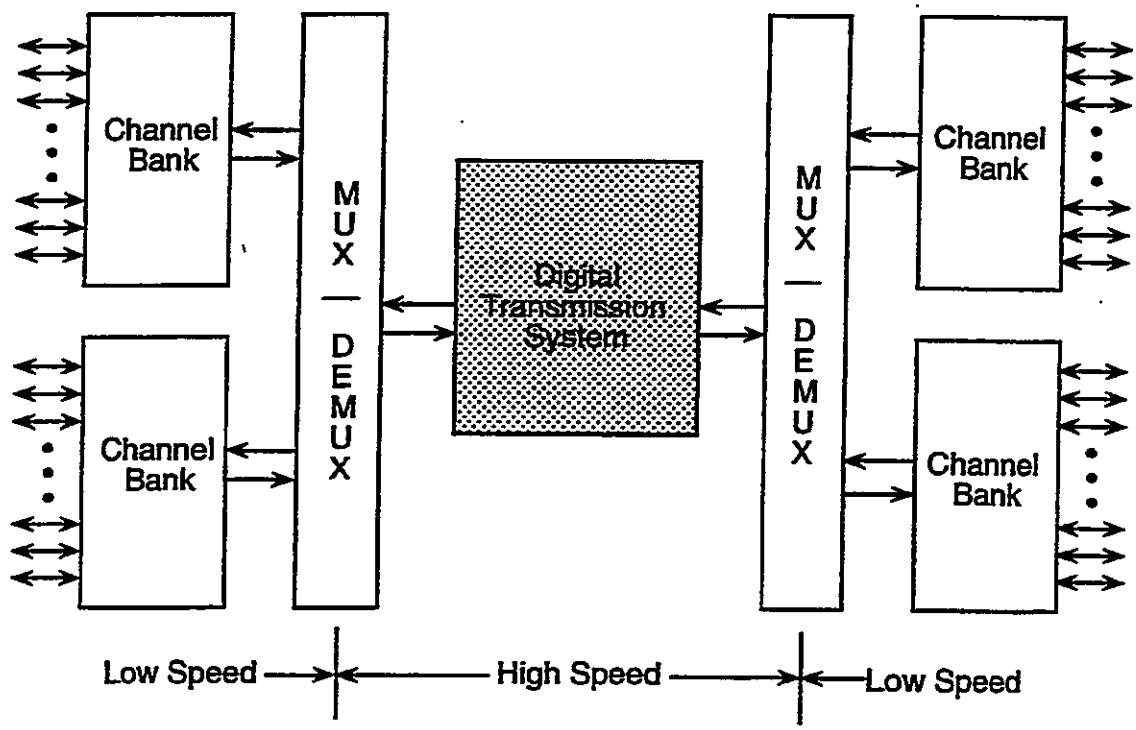
Digital Facility with Multiplexers



Key: MUX/DEMUX = Multiplexer/Demultiplexer

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DIGITAL FACILITY WITH MULTIPLEXERS

Functions

The multiplexer/demultiplexer function may be provided in one of three ways:

1. A separate multiplexer/demultiplexer unit
2. Built into a Channel Bank unit
3. Built into the transmission system equipment

Example

This illustration shows a simplified drawing of a "typical" digital facility.

We would expect to see a couple of Channel Banks, which do the analog/digital conversion on the transmit side and the digital/analog conversion on the receive side.

For protection switching, a separate protection switch unit can be built into the transmission system.

Channel Bank

The Channel Bank is an excellent example of a digital terminal that converts analog signals to digital and multiplexes them for transmission.

Let's look at it.

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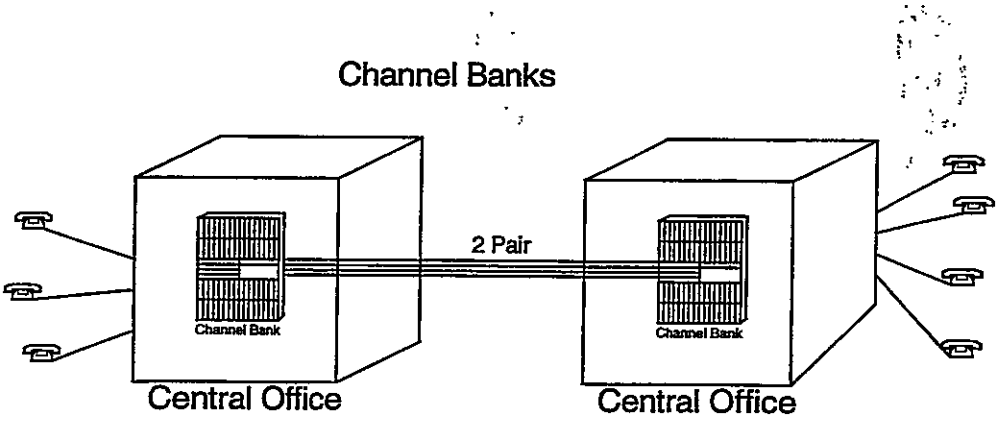
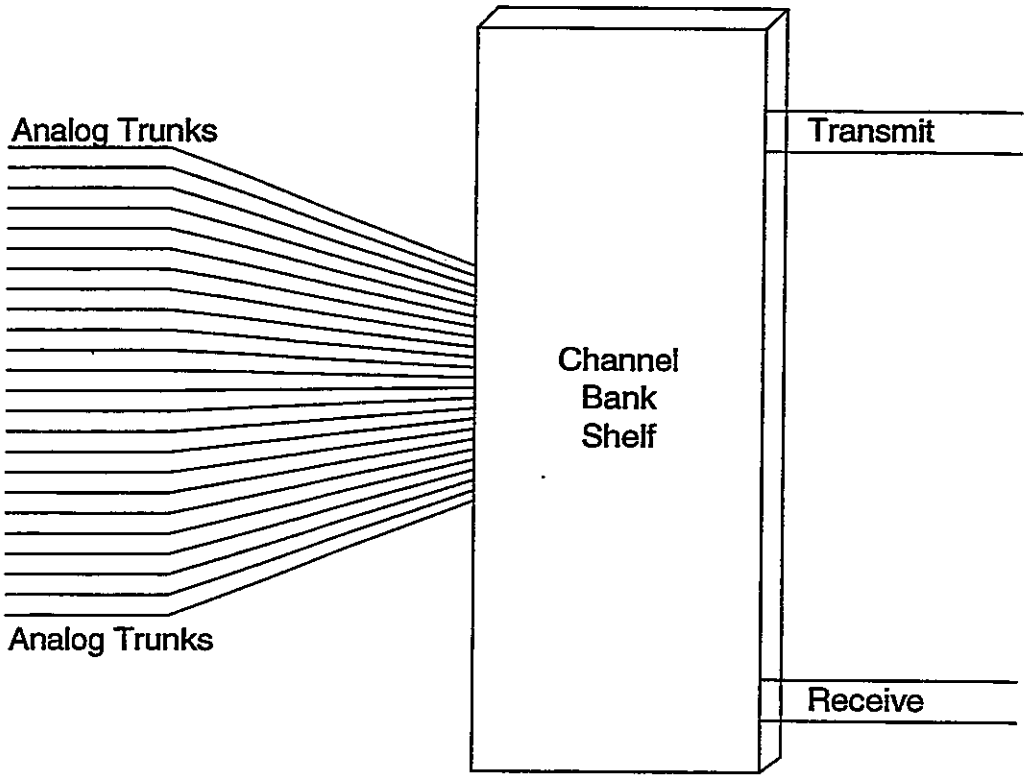
Channel Bank Arrangement



Channel Bank Shelf



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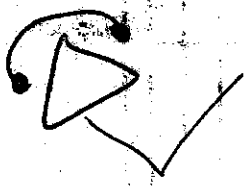
CHANNEL BANKS

Channel Banks are typically used to transport information between Central Offices.

Functions

Channel Banks have two basic functions:

- They convert analog voice to digital and vice versa (Pulse Code Modulation).
- They combine or multiplex the resulting digital streams from multiple channels into a single stream and transmit the data. At the receiving end, they demultiplex the signal.



Channel Banks are the bridge from the analog world to the digital world.

Pairs

Channel Banks typically come in pairs:

- ☆ Transmit side digitizes and multiplexes multiples of 24 calls (digroups).
- ☆ Receive side demultiplexes the signal and converts the signal to analog.

Digroups

In a basic digital system, each Channel Bank contains or uses four digroups (digital groups).

Each digroup consists of 24 channels.

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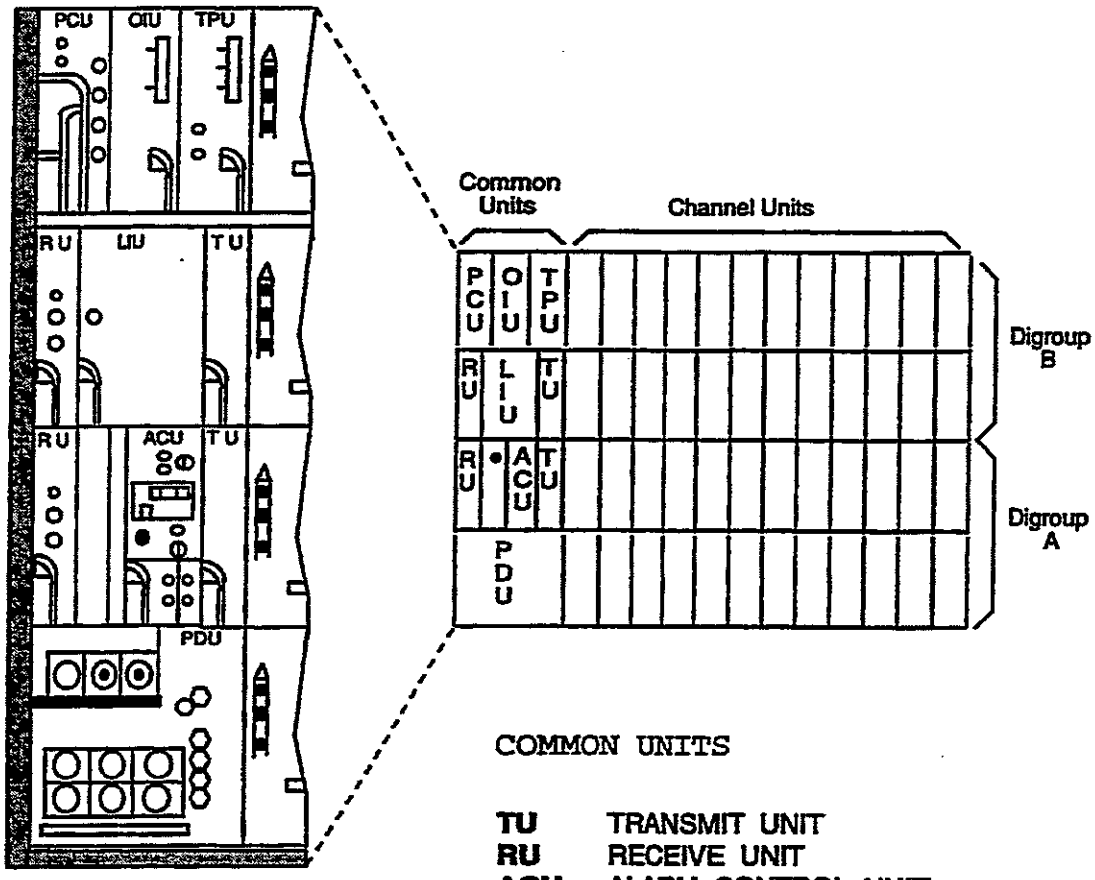
D4 Channel Bank



COMMON UNITS

TU	TRANSMIT UNIT
RU	RECEIVE UNIT
ACU	ALARM CONTROL UNIT
TPU	TRUNK PROCESSING UNIT
OIU	OFFICE INTERFACE UNIT
PCU	POWER CONVERTER UNIT
PDU	POWER DISTRIBUTION UNIT
LIU	LINE INTERFACE UNIT

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TYPES OF CHANNEL BANKS

There are various configurations of Channel Banks, from various manufacturers. The "D" (for digital) type of Channel Bank is used to generate digital signals through the digital network. D-type "banks" generally carry from 24 to 96 channels.

There is a history of D-Channel Banks, going back to the D1 and progressing in an evolutionary manner through the D5.

D4 Channel Bank

The D4 is the workhorse of the D-types. It is the most common system in use today. It is a dual digroup digital terminal, consisting of 48 channels capable of transmitting in a DS1, DS1C or DS2 format.

Modes

The D4 can operate with different digital signal outputs. Its most common operating mode feeds separate digroups (24 channels) at a DS1 rate on individual T1 lines to a Channel Bank in a distant C.O. Office.

Plug-in Units

The D4 bank has two types of plug-in units as shown in the graphic:

- Common units
- Channel units

Let's look at them individually.

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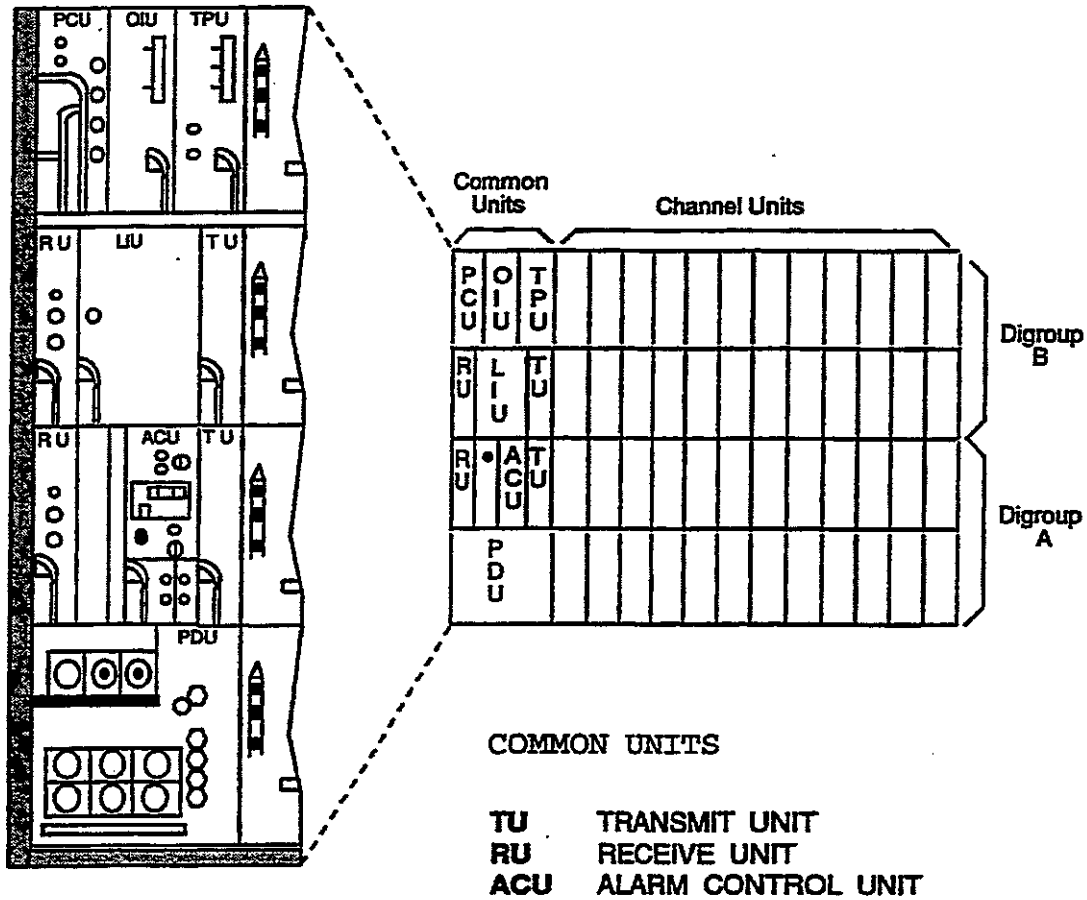
D4 Channel Bank



COMMON UNITS

TU	TRANSMIT UNIT
RU	RECEIVE UNIT
ACU	ALARM CONTROL UNIT
TPU	TRUNK PROCESSING UNIT
OIU	OFFICE INTERFACE UNIT
PCU	POWER CONVERTER UNIT
PDU	POWER DISTRIBUTION UNIT
LIU	LINE INTERFACE UNIT

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TYPES OF CHANNEL BANKS (continued)

Common Units

The common units are the circuit boards required for the operation of the Channel Bank.

Examples of common units are shown in the illustration.

It is not necessary for you to know the different types of common units.

Channel Units

Channel units are the circuit boards that connect the individual customer to the digital terminal.

The signal is converted from analog and multiplexed with the other channels within the digroup for transmission on the digital facility.

Each channel unit is dedicated to a particular channel.

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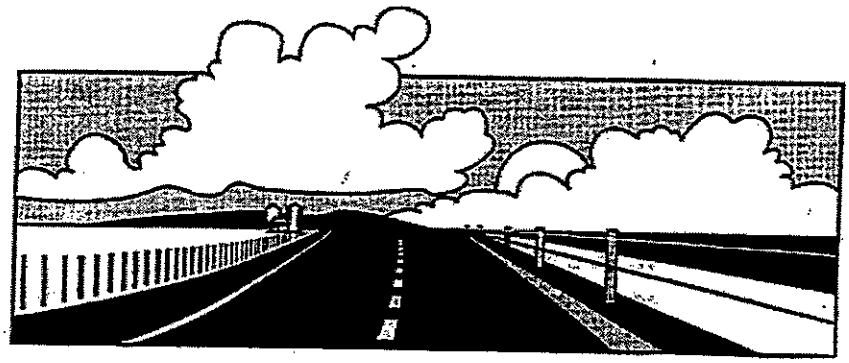

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REVIEW

1) Digital multiplexers provide a(n) interface between the different bit rates in the network.

2) List the two functions of the Channel Bank.
Mux and demux a signal by converting from A to D, vice versa.

3) Each Channel Bank contains one to four digroups. Each digroup contains 24 channels.

4) Channel banks typically come in pairs.

5) The workhorse of the D-type Channel banks, the D4, has 96 channels and 4 digroups.

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REVIEW - ANSWERS

1) Digital multiplexers provide an **interface** between the different bit rates in the network.

2) List the two functions of the Channel Bank
They convert the analog signal to digital and vice versa.
They multiplex and demultiplex the signal.

3) Each Channel Bank contains one to four digroups. Each digroup contains **24** channels.

4) Channel banks typically come in **pairs**.

5) The workhorse of the D-type Channel banks, the D4, has **48** channels and **2** digroups.

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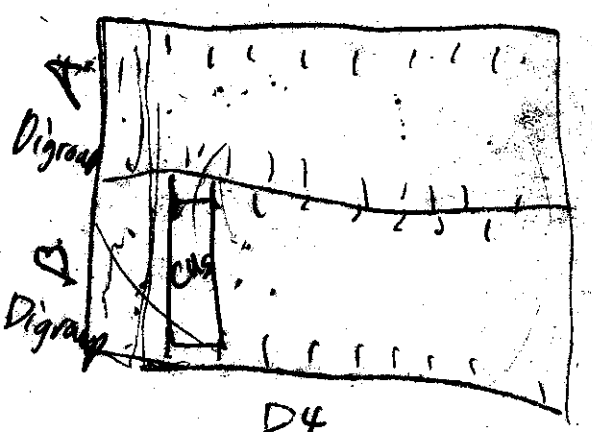
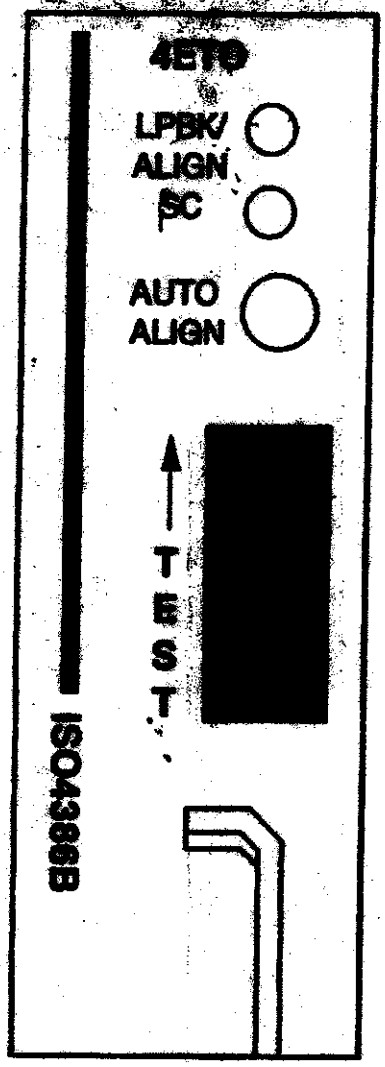


D4
Channel Bank



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D4 CHANNEL UNIT

A Channel Unit (CU), is the interface between the customer's signal and the Channel Bank.

This is shown in the graphic,

Functions

The CU performs several different functions besides passing the customer's signal to the Channel Bank.

The CU can also provide:

- attenuation and gain options
- equalization
- signaling
- impedance matching functions

The output from the CU to the Channel Bank is still an analog signal and subject to any analog impairments present on the transmission path.

Types

There are as many as 50 types of Channel Units to meet the transmission and signaling requirements of connecting circuits. The selection of a specific unit depends on the type of service to be provided or type of signaling required. For example, the service might be POTS or special services. The correct type of CU ensures proper transmission and signaling requirements for the circuit.

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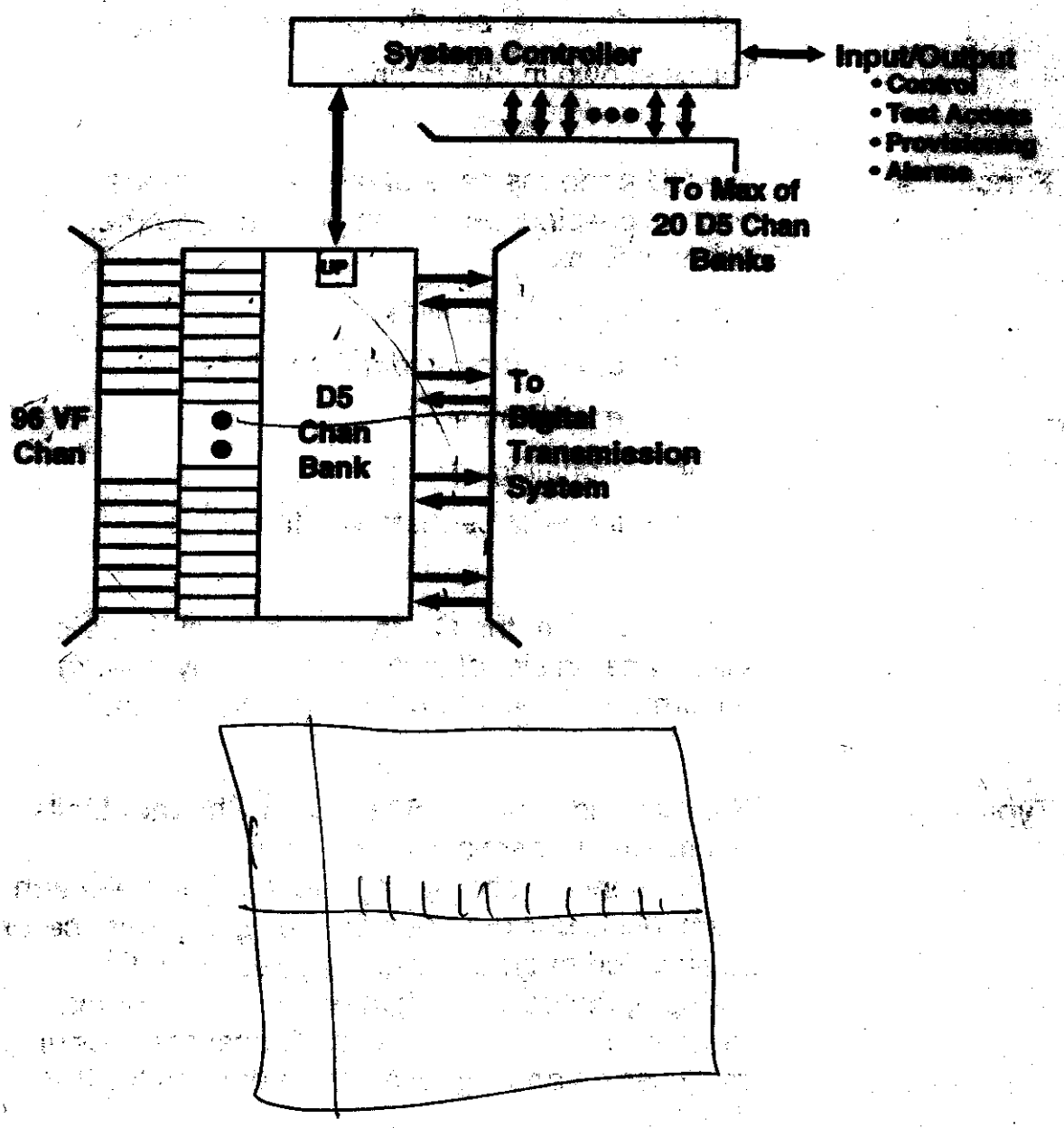
D5 Channel Bank Architecture



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D5 CHANNEL BANK

The D5 Channel Bank supports 96 channels per bank. It is the first "smart" carrier system. It is user-friendly, processor-controlled system that may contain up to twenty Channel Banks, each consisting of four groups, for a total system capacity of 1920 channels.

Description

A system controller/microprocessor controls the D5 banks and their functions (provisioning, maintenance, etc.). The system controller (actually a computer) provides test access, alarm indicators and provisioning. Provisioning can be done from a remote location.

The D5 constantly monitors individual Channel Units for performance characteristics as well as situations that may interfere with customer service.

Provisioning

A technician no longer has to turn screws and flip switches on the Channel Units to set the proper options. Now, a generic type Channel Unit is plugged into the bay, and all the options, signaling, gain or loss, and whatever else is set by the controller. The controller then stores the options in case the bank should fail. If there was a failure, the controller would restore the options as soon as the bank came back up.

Should the controller fail, the banks have the ability to run on their own.

Note that the D5 bank still puts out four standard T1 lines at 24 channels each.

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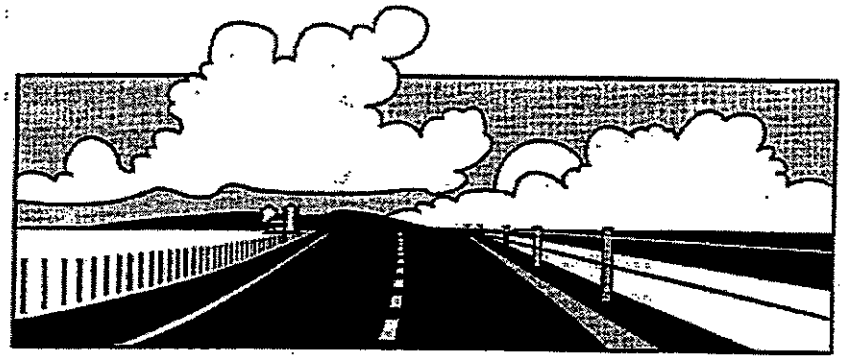

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REVIEW

1) The circuit boards required for the operation of the D4 Channel Bank are called Channel Units

2) There are more than 50 types of Channel Units to meet the transmission and signaling requirements of connecting circuits.

3) The D5's System controller controls the D5 banks and their functions, such as provisioning, maintenance, test access and alarm indicators.

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REVIEW - ANSWERS

1) The circuit boards required for the operation of the D4 Channel Bank are called **Common Units**.

2) There are more than 50 types of **Channel Units** to meet the transmission and signaling requirements of connecting circuits.

3) The D5's **controller/microprocessor** controls the D5 banks and their functions, such as provisioning, maintenance, test access and alarm indicators.

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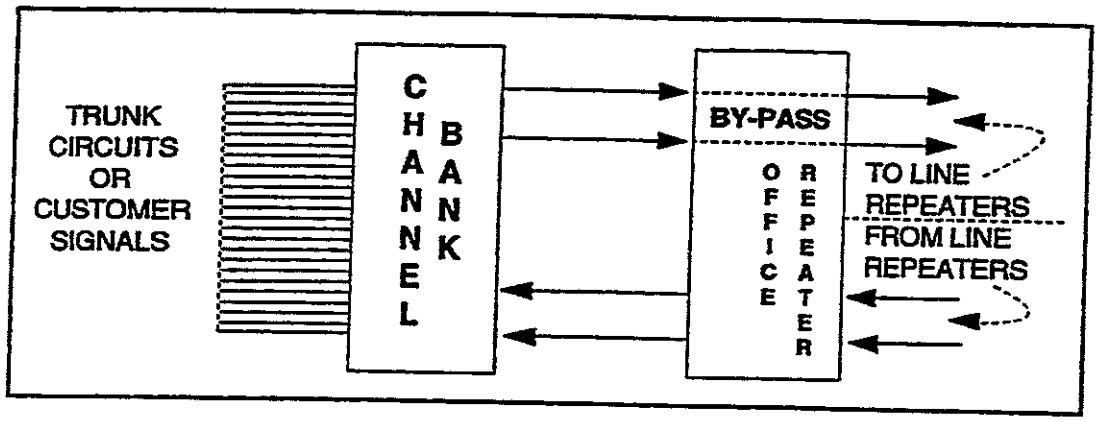
Office Repeaters



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OFFICE REPEATERS

Now let's consider some other equipment that works with Channel Banks and the digital transmission system.

Definition

Office repeaters accept, reshape and retime the digital signal.

This process is called regeneration.

As shown in the illustration, the digital signal sent from the Channel Bank at the transmitting end passes through the transmitting end office repeater without regeneration because of the close proximity of the equipment (the signal quality has not yet deteriorated enough to warrant regeneration).

Function

The office repeater accepts, reshapes and retimes the signal at the receiving end.

Location

The office repeater is located in the Central Office in a location called the ORB (for Office Repeater Bay). It is a separate component from the Channel Bank.

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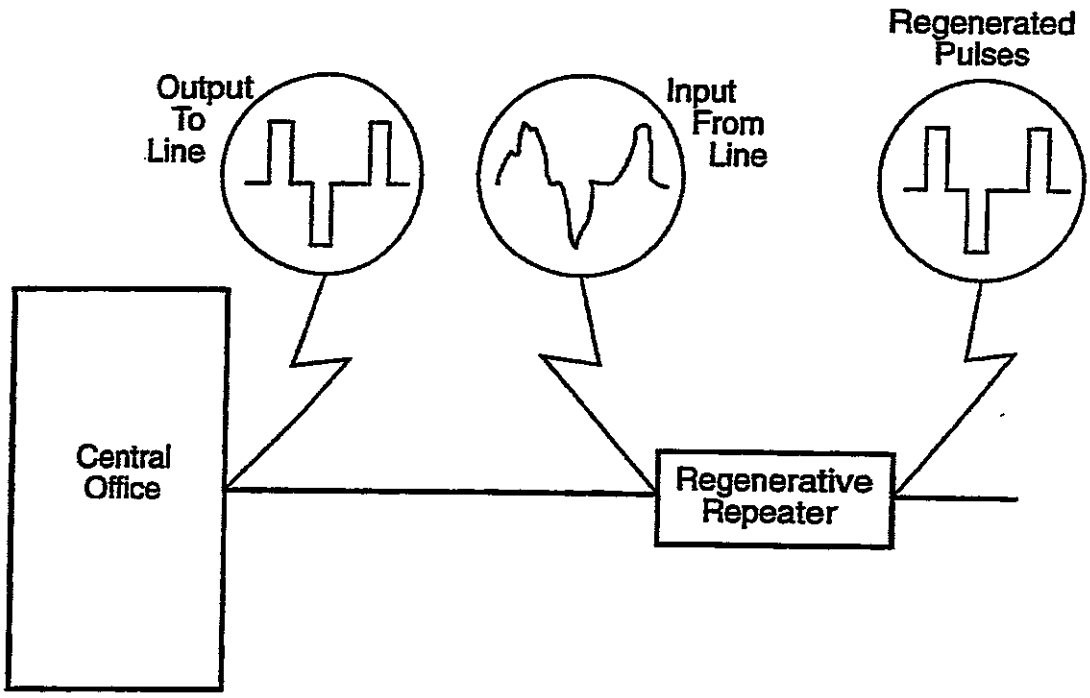
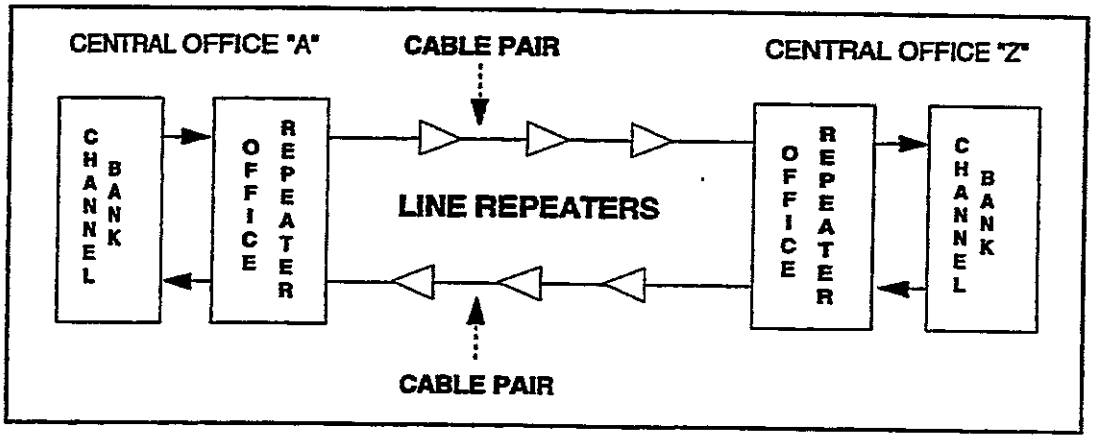
Line Repeaters





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LINE REPEATERS

Repeater Spacing

T-Carriers, like most transmission mediums, require regenerative repeaters.

In transmitting digital signals over the digital line, the signals can become attenuated and distorted.

Regenerative line repeaters are located along the digital line to regenerate or "clone" the signals being transmitted.

The signal is not merely amplified, but completely rebuilt to look like the original, as shown in the top illustration.

Digital repeaters are not amplifiers, even though there is a preamplifier in the unit that boosts the signal slightly. The digital repeater is actually a regenerator. Its function is to regenerate the digital signal.

The digital signal is accepted, restored and passed on to the next line repeater, until the signal reaches the far-end office repeater, as shown in the lower illustration.

Placed along the transmit and receive cable, the spacing depends on the gauge of the cable. Smaller gauge cable requires shorter spacing intervals because there is more resistance to the transmission of the digital signal. Line repeaters are commonly spaced every 6,000 feet on the transmission path.

The symbol for a repeater is a triangle, pointing in the direction of transmission.

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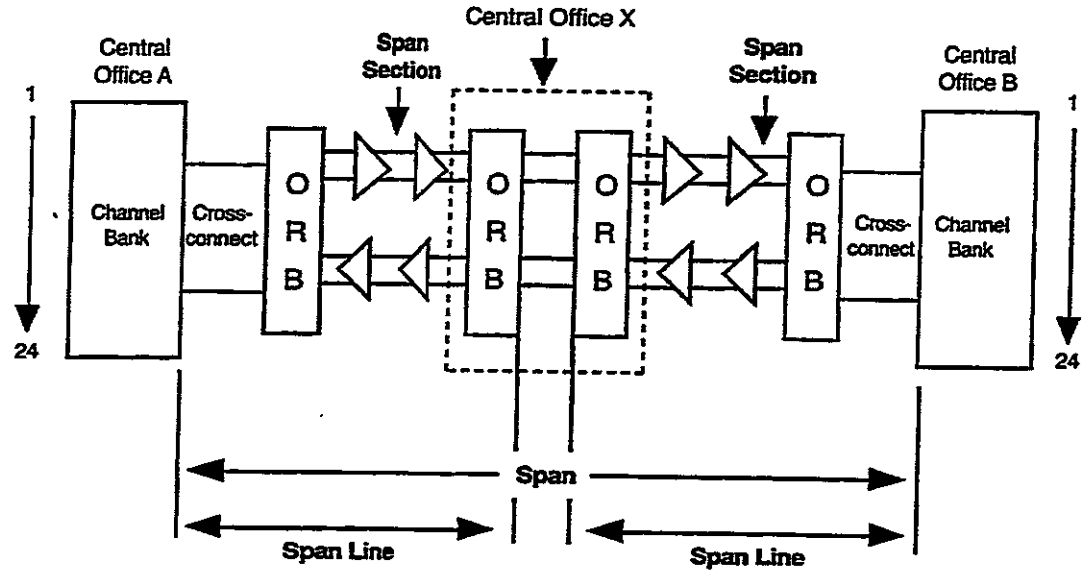
Span/Span Line/Span Section



Key: ORB = Office Repeater Bay

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SPAN/SPAN LINE/SPAN ACTION

Span

A span is part of the digital carrier system extending from the digital cross-connect in the near-end Central Office, through the line repeaters, to the digital cross-connect in the far-end Central Office. The function of a digital cross-connect bay is to interconnect carrier systems, and will be discussed in detail later in the module.

A span consists of cross-connect equipment, office repeater bays, line repeaters and cable pairs (copper or fiber) for both directions of transmission. Each span requires two cable pairs. In the illustration, one pair transmits the digital signal in the direction of Central Office A to Central Office B. The other pair transmits from Central Office B to Central Office A.

Span Line

Span lines are portions of the system between Central Offices. In our example, the portion from the cross-connect in the Central Office A to the office repeater bay in Central Office X is a span line.

Interchangeable Terms

Earlier, we mentioned that DS1 and T1 are often used interchangeably. You may hear these terms synonymously used with the term, Span Line: a T-Carrier, a T-span, and a T1 line.

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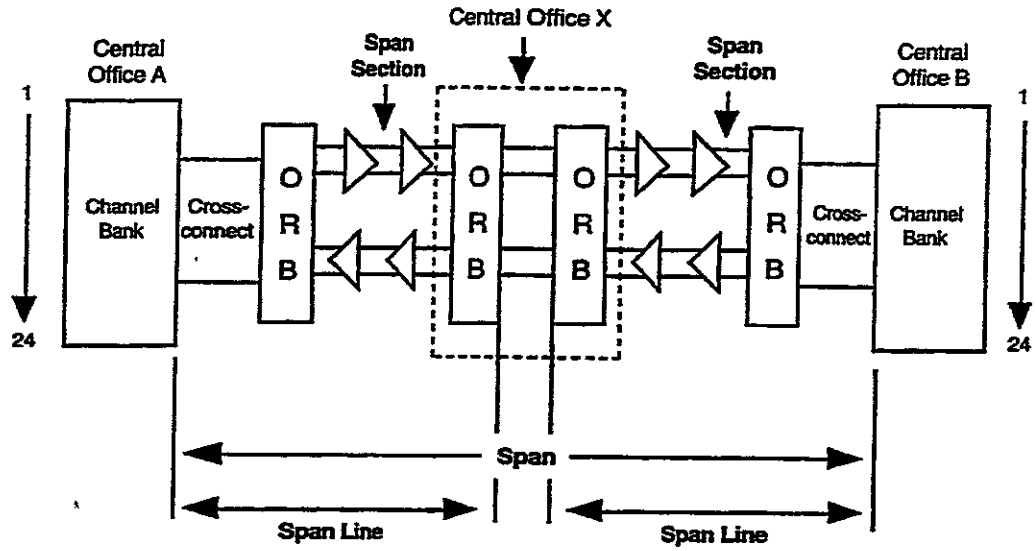
Span/Span Line/Span Section



Key: ORB = Office Repeater Bay

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SPAN/SPAN LINE/SPAN ACTION (continued)

Span Section

The portions of cable or fiber between office repeaters and each line repeater are called span sections. On copper cables, the distance from the Central Office to the first line repeater (the first span section) is 3000 feet. Span sections between line repeaters are generally 6000 feet in length, based on engineering specifications for 22 gauge copper cable. Different gauge cable (such as 24 or 26 gauge) may use repeater spacing of less than 6000 feet.

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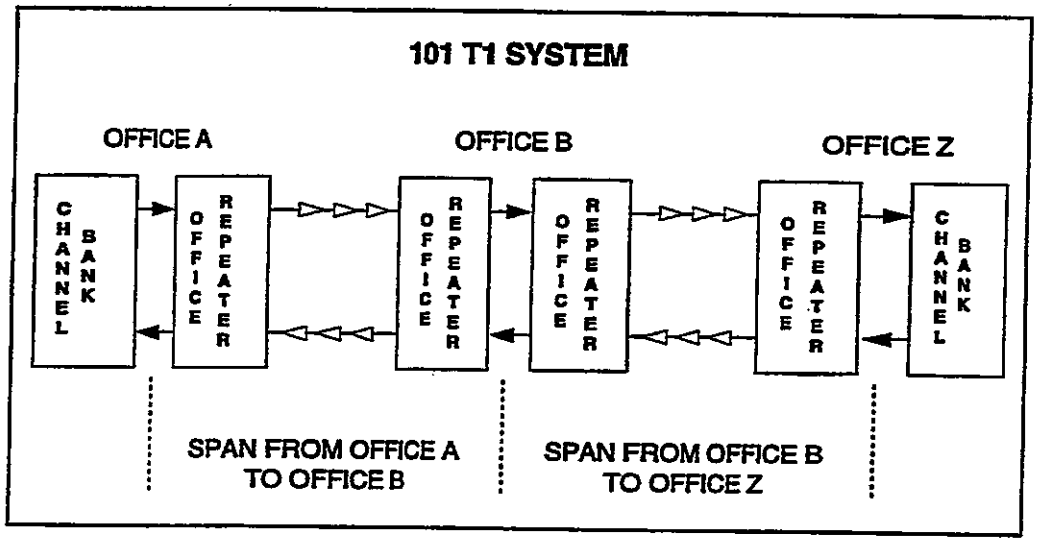
Carrier System



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SYSTEM

Extension

A system extends from the Channel Bank at the near-end office to the Channel Bank at the far-end office.

Identification

T-Carrier systems are assigned numbers for maintenance purposes.

The illustration shows the 101 T1 System extending from office "A" to office "Z."

Office "B" is an intermediate office with office repeaters but without Channel Banks.

Numbering

The number, 101, designates this system as the first T1 system between office "A" and office "Z." 102 would be the second system, and so on.

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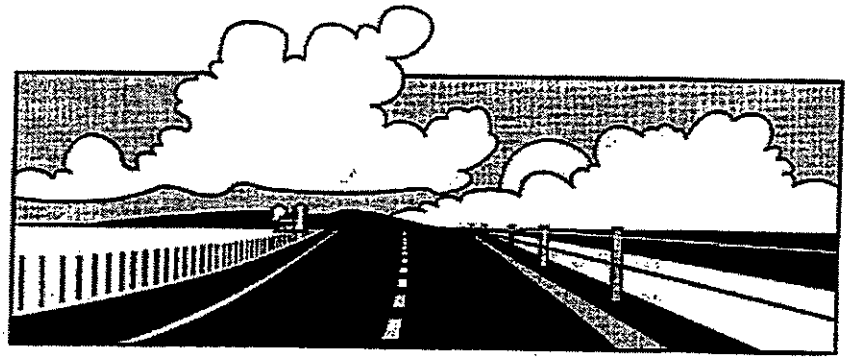

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REVIEW

1) What is the name of the piece of equipment, located in the Central Office, that accepts, reshapes and retimes the digital signal? C

a) Cross-connect
b) Channel Bank
c) Office Repeater
d) Channel Unit

2) Briefly describe what Line Repeaters do.

to preamplify and regenerate the signal

3) Generally speaking, how far apart are Line Repeaters spaced?

C

a) 9,000 feet
b) 18,000 feet
c) 6,000 feet
d) 12,000 feet

4) Match the term on the left with its description on the right.

Span Line C

a) Portions of cable or fiber between office repeaters and each Line Repeater.

Span Section a

b) Cross-connect equipment, Office Repeater Bays, Line Repeaters, and copper or fiber cable pairs, from the near-end C.O. to the far-end C.O.

Span b

c) Portions of the system between offices. Also called a T-Carrier, a T-Span and a T1 line.

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REVIEW - ANSWERS

1) What is the name of the piece of equipment, located in the Central Office, that accepts, reshapes and retimes the digital signal? **(c)**

2) Briefly describe what Line Repeaters do.
Line Repeaters regenerate or rebuild the signal being transmitted.

3) Generally speaking, how far apart are Line Repeaters spaced? **(c)**

4) Match the term on the left with its description on the right.
Span Line **(c)**
Span Section **(a)**
Span **(b)**

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CONCLUSION

This concludes Module 1, Book I.

Before taking the test, you may review the material in the module.

Clear up any questions you may have with the instructor.

Return to the beginning of Book I and review the objective.

When you are ready, ask your instructor for a copy of the test for Module 1, Book I.

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SUBJECT INDEX - BOOK I

Subject	Page
Analog amplifiers	35
Analog signal	5
Amplitude	13
Frequency	15
Analog to Digital Conversion	77
PCM steps	79
Analog voice signal	17
Binary	53
Bit	53
Bit rate	133
Byte	53
Carrier system	111
Channel Banks	169
Types of Channel Banks	171
Channel Unit	171
D4 channel unit	177
Common units	171
D4 Channel Bank	171
D5 Channel Bank	171
Data stream concentration	147
Decoding	99
Definitions	23
Demultiplexing (overview)	113
Also see Time Division Multiplexing	
Digital hierarchy	145
Digital multiplexers	165
Digital facility with multiplexers	167
Digital signal levels	133
Also see DS0, DS1, DS3	
Digital signal	61
Characteristics of digital signals	55
Digital to analog conversion	98
Digital transmission	
Advantages	45
Constraints	47

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SUBJECT INDEX - BOOK I

Subject	Page
Digroups	169
Distortion	33
DS0	133
DS1	135
Also see U S WEST DS1 Service	
DS3	143
Also see U S WEST DS3 Service	
Encoding	91
Error rate comparison	103
Factors driving network evolution	43
Filtering	99
Frequencies (audible, radio)	25
Hertz	15
Impediments to the signal	33
Interoffice Carrier	117
Line repeater	187
Loss	33
Modulation	113
Multiplexing (overview)	113
Also see Time Division Multiplexing, digital multiplexers	
Nibble	53
Noise	33
Nyquist Theory	87
Office repeater	185
Pulse Code Modulation	69
Characteristics	71
Where Pulse Code Modulation occurs	101
Quantizing	89
Regenerative repeaters	63
Sampling	85
Sampling rate	87
Single Channel Pulse Code Modulation	123
Span/span line/span section	189
System	191
Subscriber Loop Carrier	115

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SUBJECT INDEX - BOOK I

Subject	Page
T1 Carrier	137
T3 Carrier	143
Telephone transmission	3
Telephone voice network	31
Time Division	
Overview	125
Process	127
Trend to a digital world	41
U S WEST DS1 Service	153
Benefits	155
U S WEST DS3 Service	157
Benefits	159
Units of information	53
Word	53

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Introduction to Digital Technologies for COT

US*WEST*
COMMUNICATIONS

Module 1, Book II
Understanding Digital Concepts And Components

January, 2000

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DOCUMENT RELEASE NUMBER	DOCUMENT STATUS	DATE	SOFTWARE FILE NAME
0.01	Revised original course material and updated test questions	01/11/00	M1 B2 intro.doc M1 B2 ptA.doc M1 B2 ptB.doc

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INTRODUCTION

Module 1, Book II of *Understanding Digital Concepts and Components,* is comprised of the following parts:

Part C: Cross-connect Systems
Part D: Pair Gain Systems

After completing Book II, you will take a test before going on to the next module. We will only test on material in Book II; no material from Book I will be included.

Each Part will list its purpose and the subjects to be covered.

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OBJECTIVE - BOOK II

At the conclusion of Parts C and D of this module (Book II), the student will be able to correctly:

- ✔ Identify the purpose, functions, components and types of cross-connect systems.
- ✔ Identify pair gain concepts, vendor systems and components.

The student will be provided with a written test, comprised of multiple choice, matching true/false and completion type questions. During the test, the student may not refer to any reference material.

Evidence of satisfactory learning will be demonstrated by correctly completing 26 out of 33 questions on the test.

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Table of Contents

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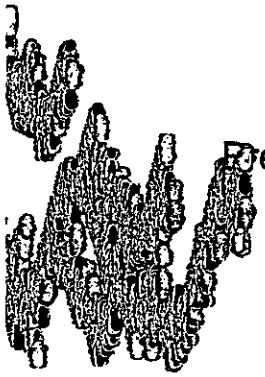
PART C: CROSS-CONNECT SYSTEMS

PURPOSE AND PREVIEW

Purpose

Various components perform cross-connect functions in the Central Office. The purpose of this section is to look at examples of these components, with an emphasis on the Digital Cross-connect System, or DCS. An understanding of the DCS is vital to anyone performing switch maintenance.



Preview

Subjects we'll be looking at include:

- ☆ Purpose and description of cross-connect systems
- ☆ Distributing frame
- ☆ DSX cross-connect system
- ☆ DCS cross-connect system
- ☆ DCS reconfiguration - concentration, segregation, Channel Bank replacement
- ☆ DCS access and testing
- ☆ Components and commands of the DCS system
- ☆ DCS vendor units
- ☆ EDSX cross-connect system
- ☆ Fiber distribution panel

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Cross-connect Frame Systems:

- Provide cross-connection and test access
- Major types include:
  - Distributing Frame Systems
  - Digital Cross-Connect Systems
  - Fiber Distributing Panels

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CROSS-CONNECT FRAME SYSTEMS

Purpose

Cross-connect frame systems provide for cross-connection of, and test access to, telephone circuits. Several types of systems have been developed to meet the specific needs of voice frequency, digital carrier and fiber-based systems.

System Types

The major types of cross-connect frame systems that are now used for modern Central Office cabling and circuit interconnection are:

- Distributing Frame Systems
- Digital Cross-connect Systems
- Fiber Distributing Panels

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Distributing Frames:

- ✔ Cross-connect outside plant cable pairs and interoffice trunks to Central Office equipment
- ✔ Provide protection from hazardous voltages entering the C.O. from outside cable

Digital Signal Cross-connect Systems:

- ✔ Interconnect digital circuits
- ✔ Provide access for testing and maintenance

Fiber Distributing Frames:

- ✔ Terminate and cross-connect fiber media

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CROSS-CONNECT FRAME SYSTEMS, continued

DF — Distributing Frame (DF).

The Distributing Frame (DF) provides the means for cross-connecting outside metallic cable pairs to Central Office equipment. Examples of circuits that are cross-connected at the DF include voice frequency subscriber loop cable pairs, and interoffice cable pairs (trunks).

The Distribution Frame can also provide electrical protection from hazardous voltages and/or currents that may enter the C.O. via the outside plant cable. Electrical protection is usually provided with plug-in protector units. The protectors also provide means for test access and temporary disconnection.

DSX, DCS, EDSX — Digital Signal Cross-connect Systems.

Digital signal cross-connect systems (DSX, DCS, EDSX) are used to interconnect circuits conforming to various digital signal levels - DS1, DS1C, DS3, and DS4. In addition, digital cross-connect systems provide access for testing and maintenance of circuits.

FDP — Fiber Distribution Panel

Termination, cross-connection and testing access of fiber media are provided by the FDP. An FDP is comprised of fiber connectors, connector assemblies, shelves, and trays with provisions for cross-connecting and interconnecting fiber optic cable. The accelerating growth of interoffice fiber optic facilities and fiber-in-the-loop applications have prompted the growing use of complete fiber frame systems. We will cover the subject of fiber optics extensively later in the module.

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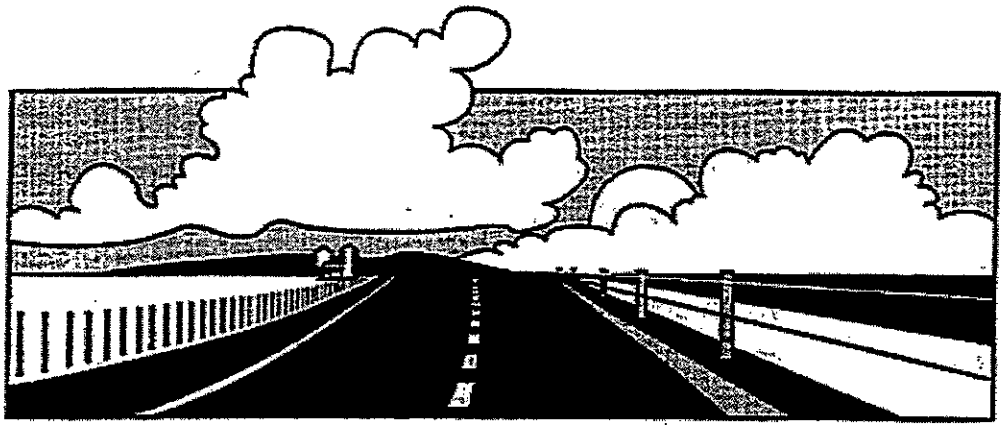

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REVIEW

Write the appropriate initials beside the statement.

1) The following statements describe Distributing Frames, Digital Signal Cross-connect Systems, and Fiber Distribution Panels. In the space beside the statement, write "DF" for Distributing Frames, "DSX/DCS" for Digital Signal Cross-connects, and "FDP" for Fiber Distribution Panels. More than one answer may apply.

DF — Cross-connects outside plant cable pairs to the Central Office equipment

FDP — Cross-connects and terminates fiber media

DSX/DCS — Provides test access.

DSX/DCS — Interconnects circuits at various digital signal levels.

DF — Provides protection from hazardous voltages entering the C.O.

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REVIEW - ANSWERS

1)

DF	Cross-connects outside plant cable pairs to the Central Office equipment.
FDP	Cross-connects and terminates fiber media.
DF, DSX/DCS, FDP	Provides test access.
DSX/DCS	Interconnects circuits at various digital signal levels.
DF	Provides protection from hazardous voltages entering the C.O.

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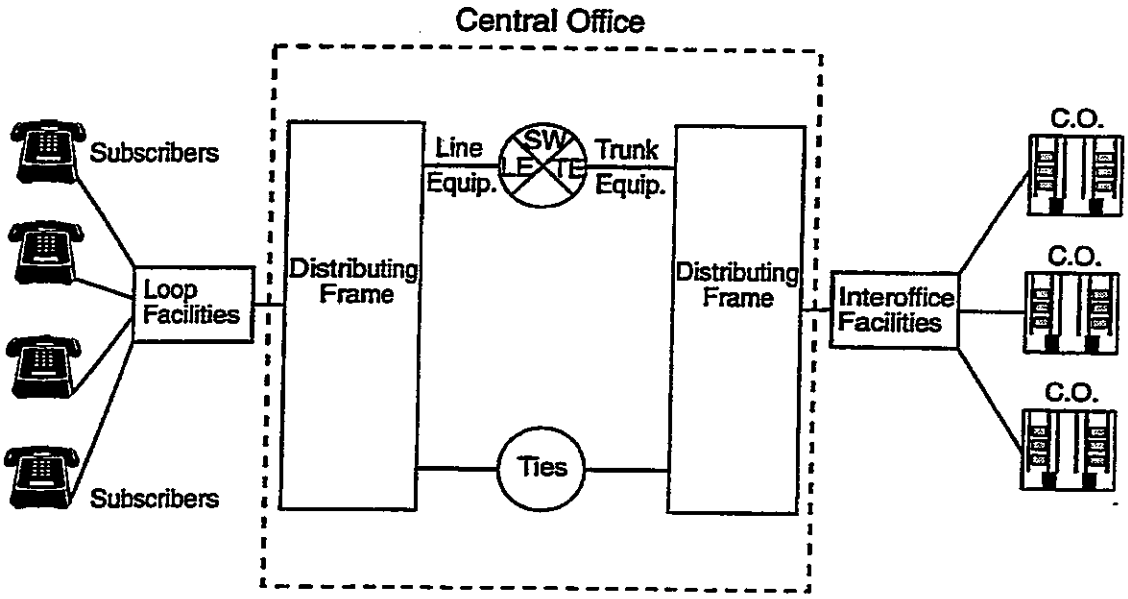
Distributing Frame System



Key: SW = Switch
LE = Line Equipment
TE = Trunk Equipment

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THE DISTRIBUTING FRAME

A system that takes up a large amount of space in Central Offices are Distributing Frames, commonly referred to as "frames" or as "main frames."

Purpose

Put in its simplest terms, the purpose of a Distributing Frame is to connect the telephone number in the switch with the subscriber's cable pair entering the Central Office. In other words, we must have some way of getting dial tone from the switch to the subscriber's facilities.

LEN

Every subscriber is issued a four digit Line Equipment Number, or LEN, in the switch. Each subscriber's LEN (also referred to as Line Equipment) is hard-wired to the back of the frame.

Connections

Each subscriber's cable pair enters the Central Office at the cable vault and is fed up to the frame. The Line Equipment and the subscriber's cable pair are then cross-connected at the frame via "jumpers." In addition, Distributing Frames terminate and cross-connect interoffice trunks and voice frequency trunk cable pairs.

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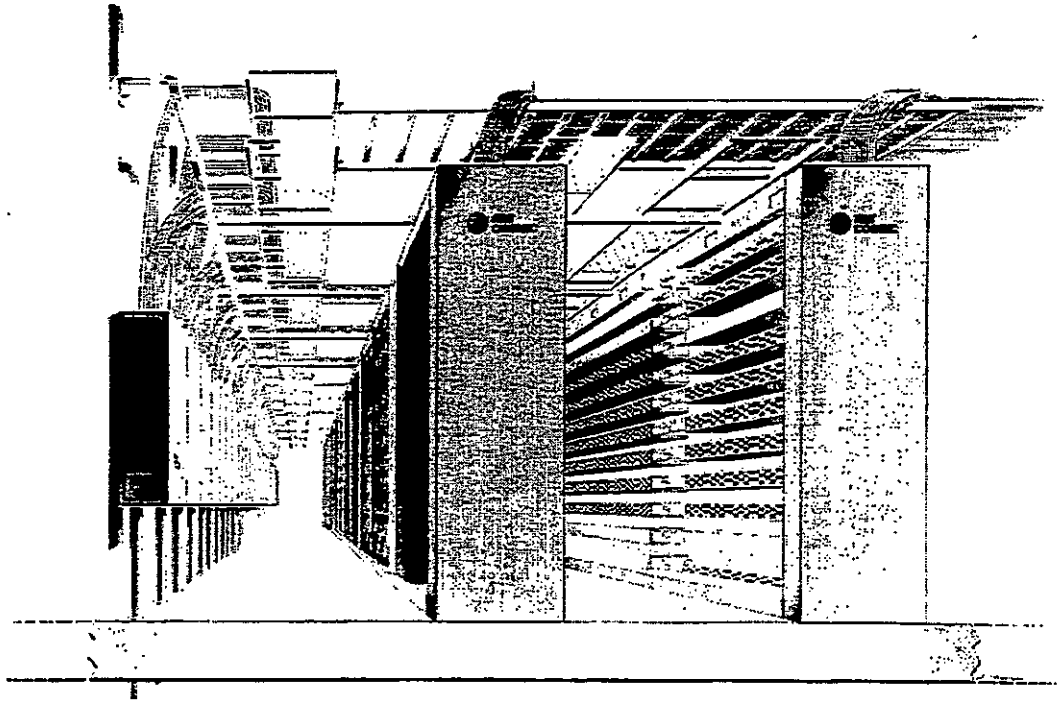
Distributing Frame Functions

- Cross-connection - completed by connecting outside plant terminations to C.O. terminations via jumpers
- Electrical protection - voltage and current protection provided by plug-in protector units
- Test access - provides an access point where circuits can be opened and tested
- Temporary disconnection - permits a circuit to be opened without removing cross-connections

AT&T's Cosmic Frame Lineup



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DISTRIBUTING FRAME FUNCTIONS

Cross Connection	A cross-connection is the electrical connection of a circuit to provide services to customers. This includes Plain Old Telephone Service (POTS), trunks, and special services. Cross-connections are usually completed by connecting outside plant terminations to Central Office equipment terminations with solid conducting wires called "jumpers."
Electrical Protection	Protection against hazardous voltages and currents can be provided at Distributing Frames. Voltage and current protection are provided via protector units which plug into outside plant connecting apparatus.
Test Access	Distributing Frames provide an access point where circuits can be physically opened and tested. Virtually all Distributing Frame terminations have bridged test access points for testing. The Distributing Frame test access point is commonly provided by a test field or test points on protected connectors.
Temporary Disconnection	Distributing Frame equipment permits a circuit to be opened without removing cross-connections. Temporary disconnection is usually accomplished by pulling a protector unit to a detent position.

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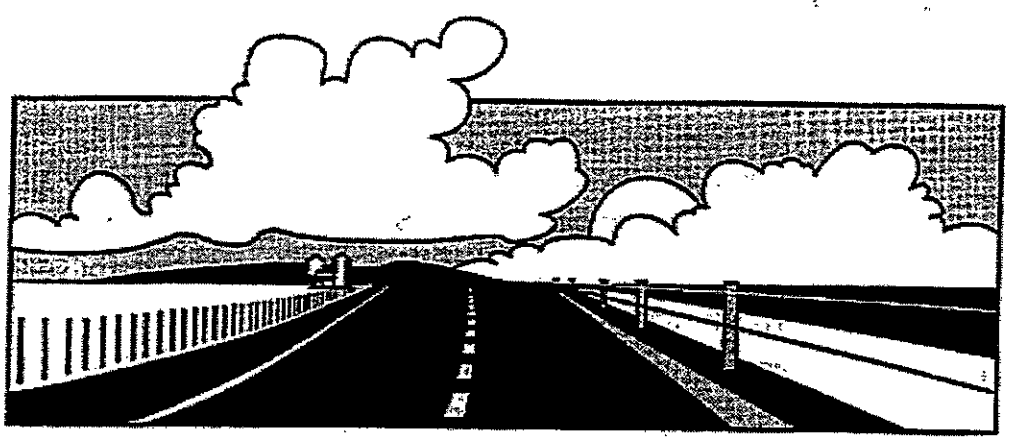

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REVIEW

1) The purpose of a Distributing Frame is to connect the line equipment in the switch with the subscriber's cable pair entering the Central Office.

2) True or false. Distributing Frames also terminate and cross-connect interoffice trunks. true

3) In the Distributing Frame, the cross-connections between the outside plant terminations and Central Office equipment terminations are done with solid conductor wires known as jumpers.

4) fuse (heat coils) units provide the voltage and current protection.

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REVIEW - ANSWERS

1) The purpose of a Distributing Frame is to connect the **telephone number** in the switch with the subscriber's **cable pair** entering the Central Office.

2) True or false. Distributing Frames also terminate and cross-connect interoffice trunks. **True**

3) In the Distributing Frame, the cross-connections between the outside plant terminations to Central Office equipment terminations are done with solid conducting wires known as **jumpers**.

4) **Protector** units provide the voltage and current protection.

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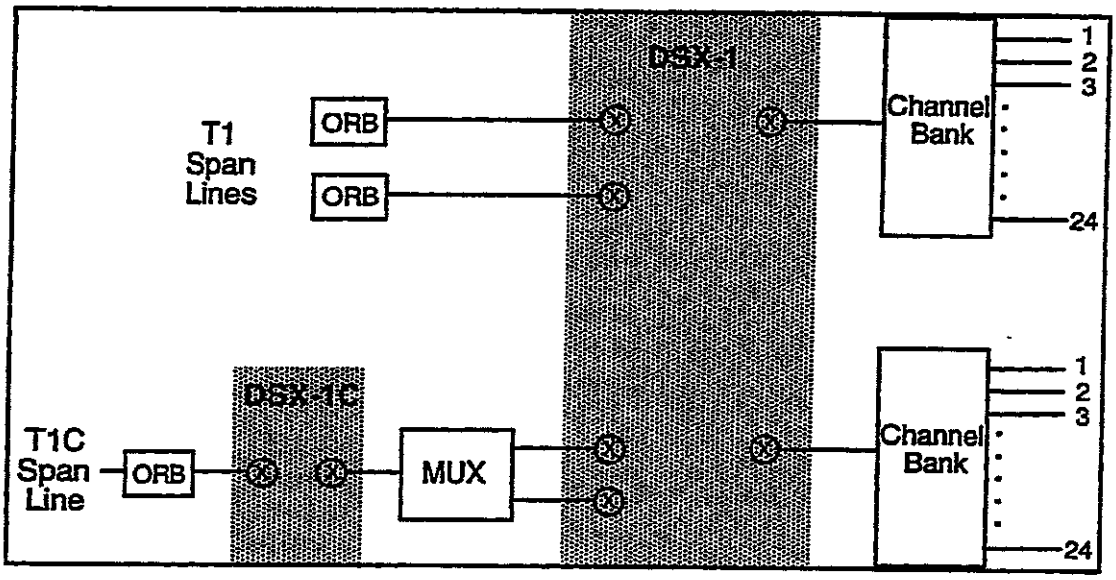
Digital Cross-Connect Bay (DSX)



Key:
ORB = Office Repeater Bay
MUX = Multiplexer that converts from the DS1C bit rate (3.152 Mbps) to the DS1 bit rate (1.544 Mbps) and vice versa.

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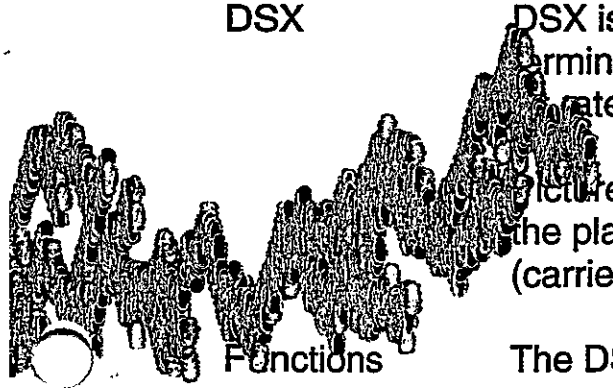
DIGITAL CROSS-CONNECT SYSTEMS

Let's now move on to some equipment in the Central Office that is found around T-Carrier lines and Channel Banks. Channel Banks are connected together to make up the digital network, using digital cross-connect technology.

We will examine three components: DSX, DCS and EDSX. Let's start first with a look at the DSX.

DSX

DSX is the common term for equipment used to terminate and cross-connect digital signals at a given rate without cross-connecting lower rate signals.



Pictured are two DSX cross-connect bays. These are the places in the Central Office where all the span lines (carrier lines) and the Channel Banks appear.

Functions

The DSX bay provides the following functions:

- ❑ Cross-connection
- ❑ Patching
- ❑ Access points

Purpose

The basic purpose of the DSX cross-connect bay is to connect span lines to Channel Banks. It also provides a place where we can move a failed span line to a spare span.

Access Points

In addition, it provides the access points for technicians. DSX panels provide access points for signals transmitted through a digital transmission system. The access points are used for troubleshooting and routine maintenance.

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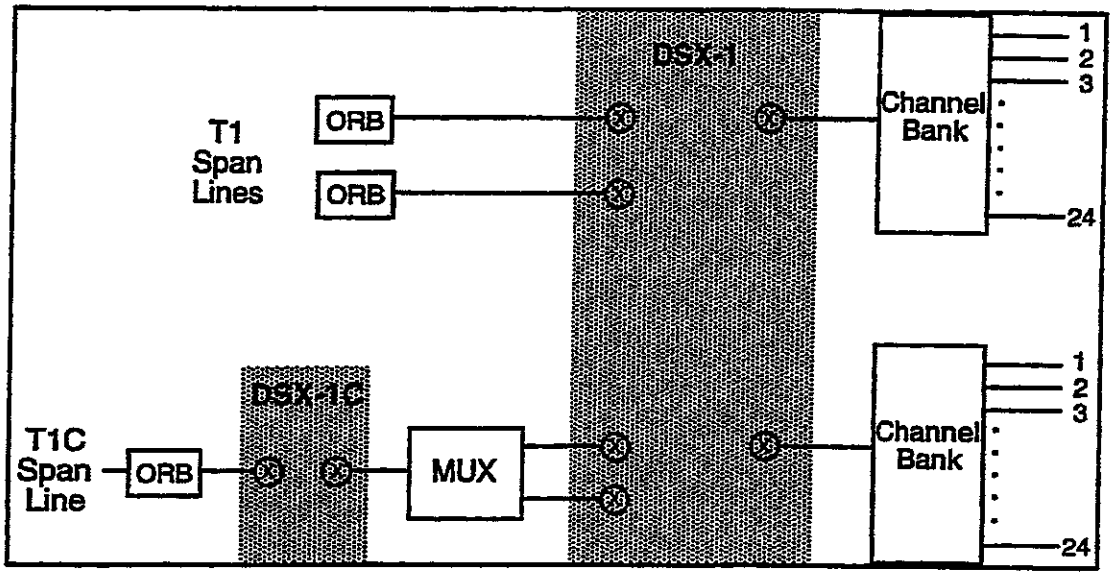

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DSX

System Route

The normal route for a carrier system is through a hard-wired jumper which connects the span line to the Channel Banks. This is an actual wire running behind the Channel Bank bay. The front of the DSX bay provides patching access, through the use of removable patch cords. In the event of a span line failure, technicians reroute the signal from the banks to a spare line via the patch cords.

Separation

Due to the possibility of interference from various signals, we must separate the different speeds. The right hand side of the illustration shows a DSX-1 bay [redacted] in order to keep crosstalk or induction from [redacted] signals. The DS1 signals are [redacted] at other locations one might find a DSX-1C or a DSX-2 bay, as shown in the left of the illustration. Each [redacted] requires its own bay.

Bays

DSX bays include:

- DSX-1
- DSX-1C
- DSX-2
- DSX-3

The suffix (1, 1C, 2, 3, etc.) corresponds to the digital level.

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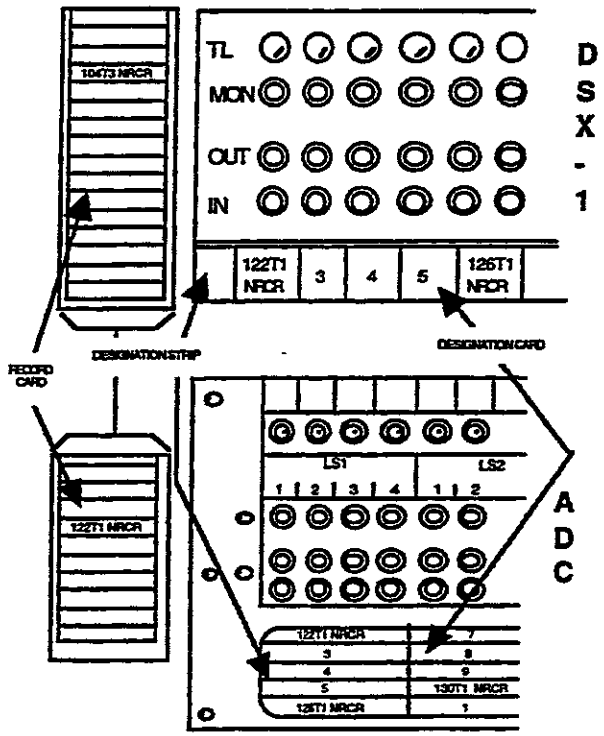
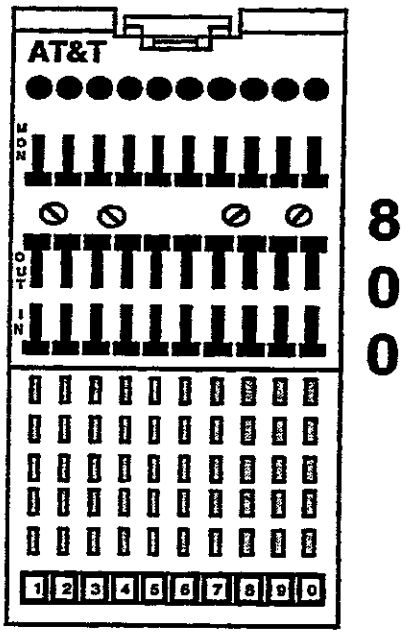
DSX Panels





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DSX, continued

The term, DSX-1, is actually the name for an equipment bay, manufactured by AT&T

Bay Types

There are three commonly used bays: the AT&T bays: the DSX-1 and the newer 800 type; and, the ADC Telecommunications bay. All use jack/plug jumpers to facilitate patching of circuits

Panels

Each panel of the bay has a designation strip beside it or possibly above or below it, to hold cards indicating the equipment connected to each set of jacks. The illustration shows examples of the panels.

Jacks

The OUT jack of one panel can be cross-connected to the IN jack of another panel. MON (monitor) jacks allow in-service monitoring.

Test Access

These jacks (IN, OUT, MON) can be used for test access to a signal stream. Using a test set, the technician can generate a test signal input to the system and can receive the signal output from the system. The signal can then be tested for various parameters.

When you plug into the monitor jack, the panel Trouble Lamps (TL) at both ends of the cross-connect illuminate. This aids in finding both ends of the circuit.

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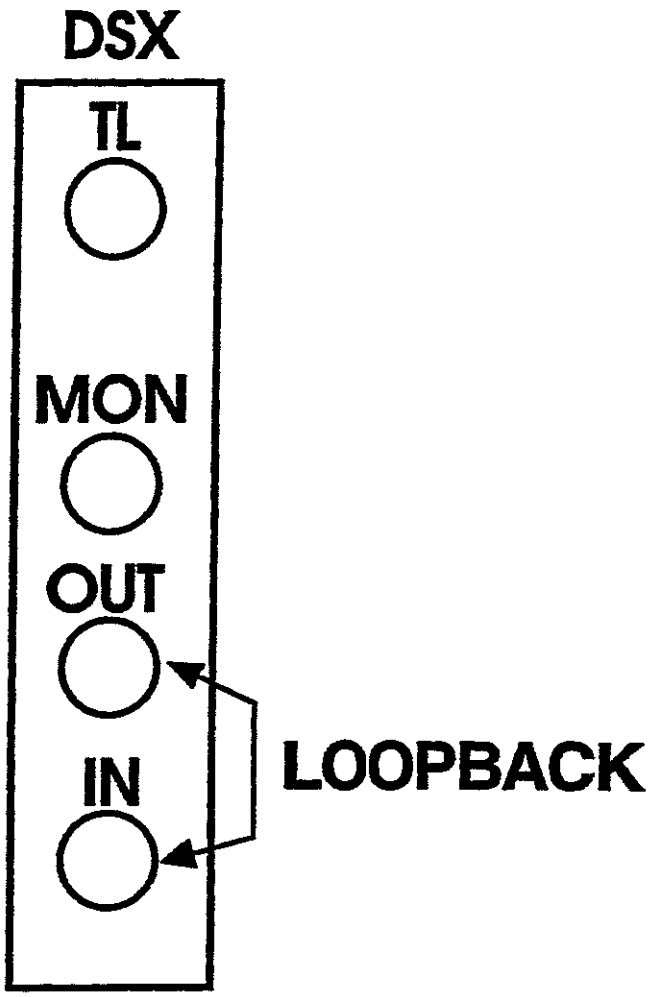

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DSX, continued

Looping

The DSX does not have alarms that indicate problems. The carriers on either side show alarms when there are problems. To isolate the problem, the DSX is "looped" through the IN and OUT jacks to test the carrier. A loopback involves the use of a test set to insert a test signal at one end of the transmission system, looping the distant end to check the proper operation of the system.

Patching

Patching of circuits occurs when it has been determined that the facilities between the carrier terminals are bad. Patch cords are used to reroute traffic from one digital carrier to another, in order to restore failed service.

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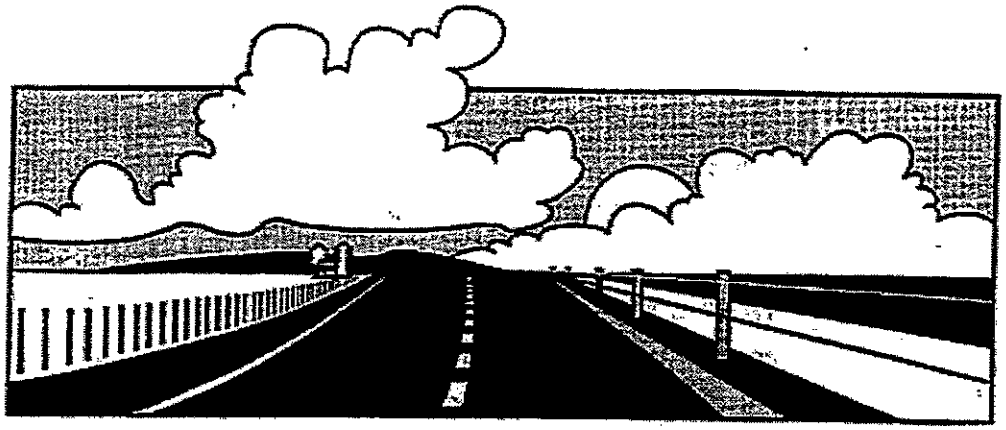

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REVIEW

1) The basic purpose of the DSX is to connect Span lines to Channel Banks.

2) DSX is the common term for equipment used to terminate and cross-connect digital signals at a given bit rate without cross-connecting lower rate signals.

3) Write the type of DSX bays required for the following digital signal levels.

DS1-C	DSX-1C
DS2	DSX-2
DS3	DSX-3

4) On the panel of the DSX bay, what jacks are used for test access to the signal stream?

in, out, mon

5) Patch cables are used to reroute traffic from one span line to another, in order to restore failed service.

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REVIEW - ANSWERS

1) The basic purpose of the DSX is to connect **span lines** to **Channel Banks**.

2) DSX is the common term for equipment used to terminate and cross-connect digital signals at a given bit rate **without** cross-connecting lower rate signals.

3) Write the type of DSX bays required for the following digital signal levels.

DS1-C	**DSX-1C**
DS2	**DSX-2**
DS3	**DSX-3**

4) On the panel of the DSX bay, what jacks are used for test access to the signal stream? **IN, OUT, MON**

5) **Patch cords (or jumpers)** are used to reroute traffic from one span line to another, in order to restore failed service.

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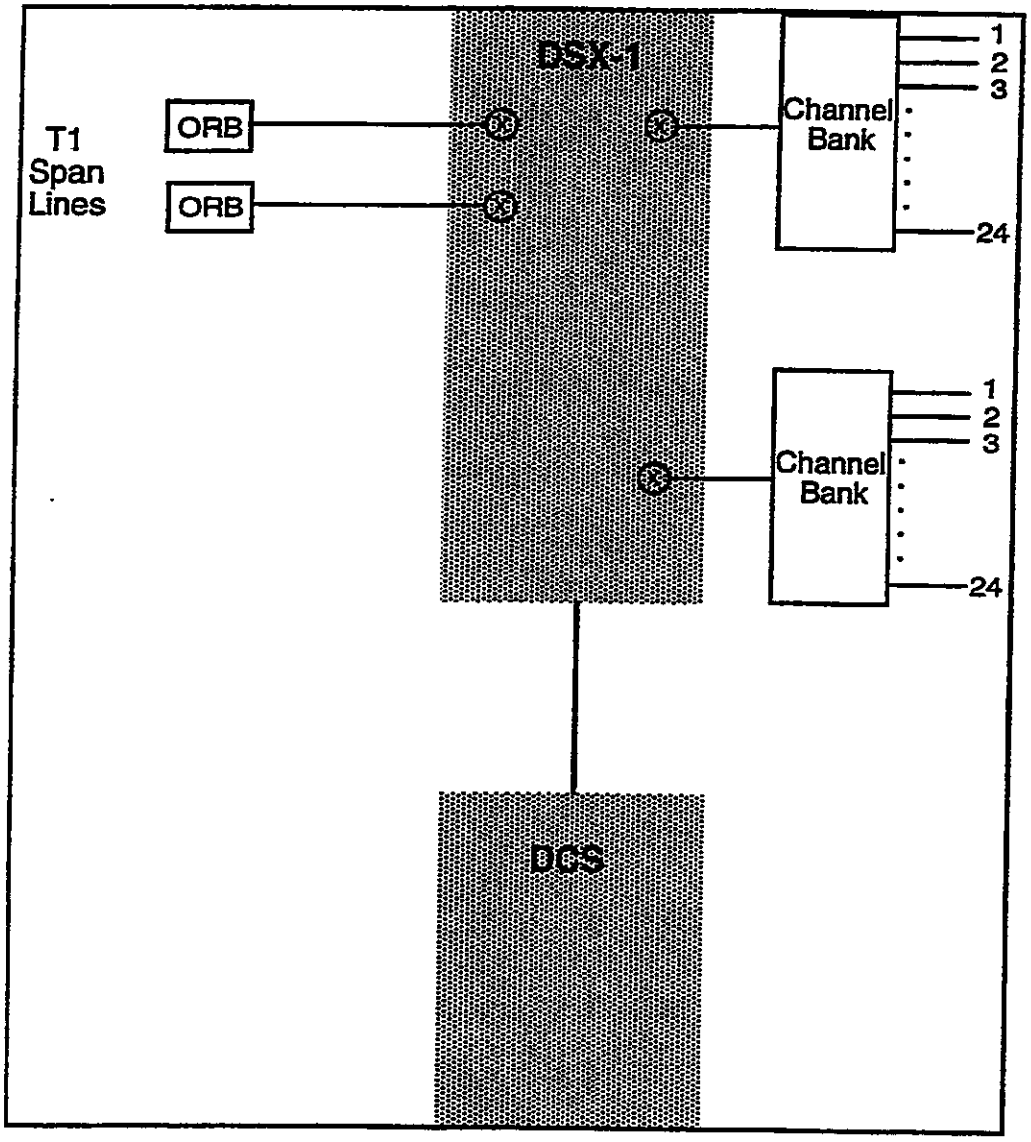
Digital Cross-Connect System



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DCS - DESCRIPTION

Introduction

The term, "digital cross-connect system," is used to describe a family of equipment that terminates signals at the DS1 rate and provides the capability to cross-connect individual channels at a DS0 rate. It is referred to as DCS. Vendors have their own names for this system, such as Tellabs' TCS (T-Carrier Cross-Connect System) or AT&T's DACS (Digital Access Cross-Connect System).

DCS

The illustration introduces us to DCS. The DCS does not replace the cross-connect bay but rather, supplements it. Where the DSX bay cross-connects entire carrier systems, the DCS unit goes further. DCS units provide:

- ✔ Digital signal cross-connections. The DCS is a processor-driven device that makes electronic cross-connects.
- ✔ Test access. The DCS can be configured for different test access arrangements either locally or remotely.
- ✔ System reconfiguration. The DCS enhances the network with its ability to efficiently reconfigure digital circuits.

Description

A standard DCS unit interfaces with carrier systems. It takes each of the incoming systems and according to instructions, breaks them down to the DS0 level. Then it can cross-connect individual circuits to other carrier systems. All this is done without any conversion to analog. It is usually accomplished by means of commands entered into an administrative interface.

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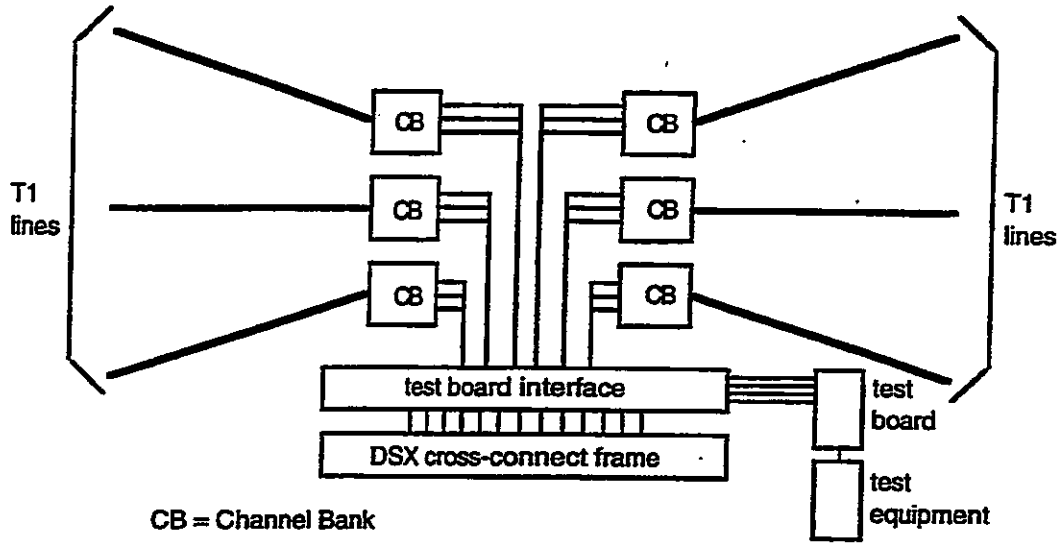
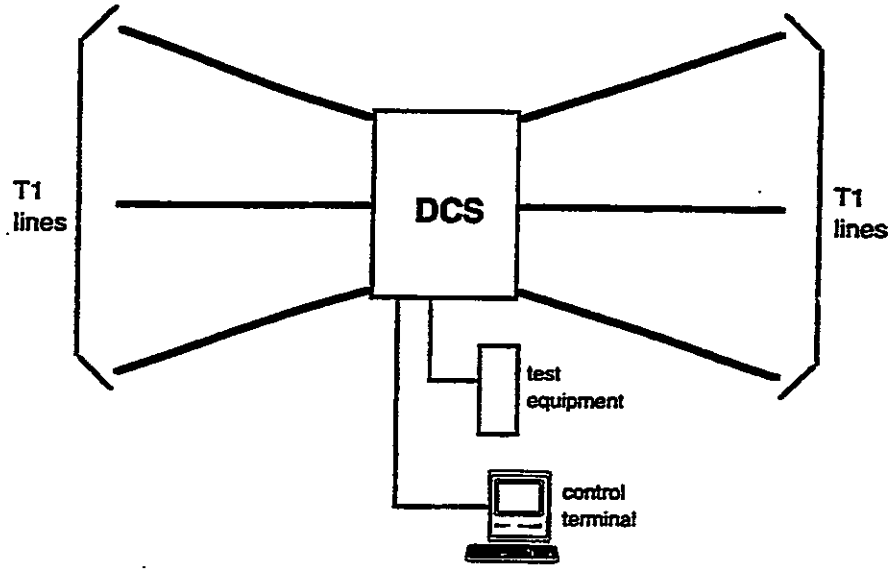


Traditional means of DS0 cross-connection



Same application using **DCS**

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DCS - DESCRIPTION

Let's compare the DSX you have just learned about, to DCS.

DSX

The DSX frame uses physical jumpers to cross-connect DS1 signals. All 24 DS0 channels are cross-connected at the same time. If individual DS0 channels are to be cross-connected, they would have to be converted back to analog, using a Channel Bank.

DCS

With DCS, cross-connections are made electronically, instead of manually. DCS is a fully electronic cross-connect frame that can establish cross-connections between individual channels or even sub-channels of the carrier system. These cross-connections are made under control of an electronic processor which is built into the DCS frame. The processor stores cross-connect information, and, as well, offers test capability.

Each DS1 provides 24 DS0 channels which can be cross-connected. AT&T's DACS 1 can terminate up to 128 DS1 signals.

Purposes & Functions

No matter what type of Central Office the DCS is used in, it serves multiple purposes. We will look at some of its functions, such as:

- ▲ Reconfiguration (concentration, segregation, Channel Bank replacement)
- ▲ Access and Testing

First though, a review.

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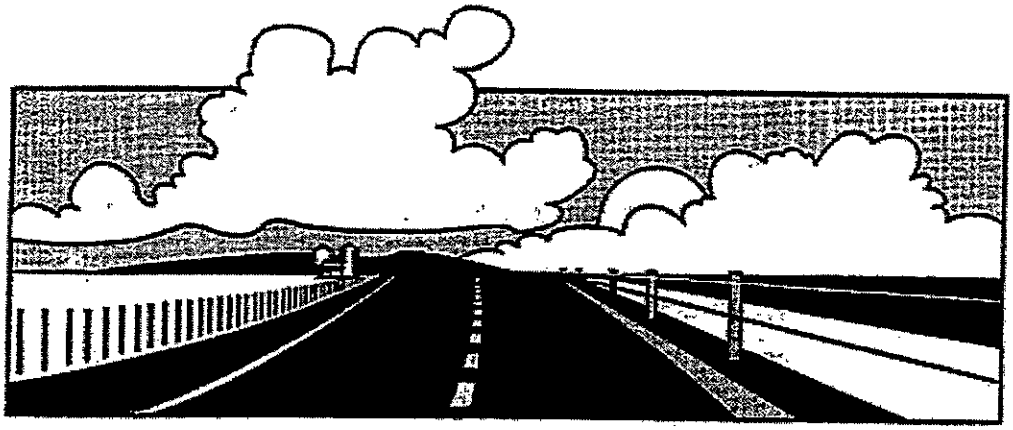

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REVIEW

1) True or false. With a DCS, if individual DS0 channels are to be cross-connected, they [illegible] have to be converted back to analog at the Channel Bank. T

2) Two attributes of the DCS system is its ability to provide cross-connects at the DS1 or DS0 rate, and to provide test access. What is its third attribute? [illegible] reconfiguration

3) With DCS, cross-connects are made electronically, instead of manually.

4) The DCS processor can store cross-connect information.

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REVIEW - ANSWERS

1) True or false. With a DSX, if individual DS0 channels are to be cross-connected, they would have to be converted back to analog at the Channel Bank. **True**

2) Two attributes of the DCS system is its ability to provide cross-connects at the DS1 or DS0 rate, and to provide test access. What is its third attribute? **Its ability to provide system reconfiguration.**

3) With DCS, cross-connects are made **electronically**, instead of manually.

4) The DCS processor can **store** cross-connect information.

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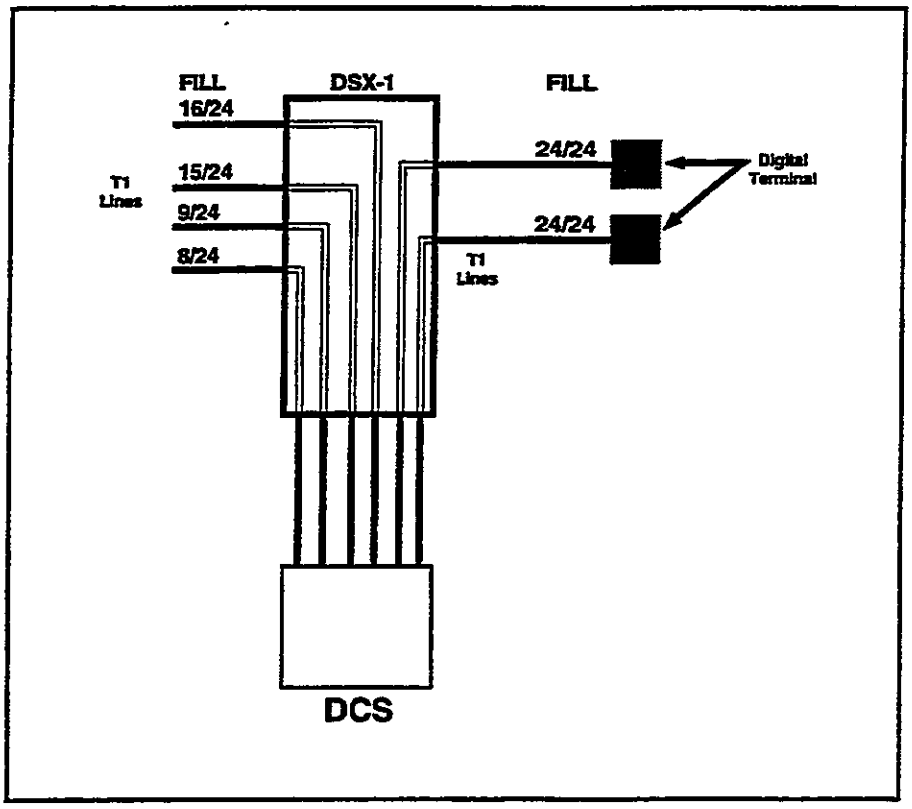
Concentration



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RECONFIGURATION - CONCENTRATION

Reconfiguration [illegible] DCS units have the ability to reconfigure the system. We will cover several examples of reconfiguration:

- ✔ Concentration
- ✔ Segregation
- ✔ Channel bank replacement

Concentration Concentration refers to eliminating unfilled DS0 slots from incoming DS1 lines and repackaging the active slots onto fewer DS1 channels.

Example In the illustration there are four incoming carrier systems that are less than fully utilized. There are only 48 time slots occupied out of the 96 that are available. By routing these into a DCS unit, we can move all of the signals into only two carrier systems, saving two spare lines.

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Special Services

- ✔ Voice, video and data circuits which require special attention
- ✔ Data, video or voice communications utilized by business and government

POTS:

- ✔ Residence and non-PBX business stations which require no special attention
- ✔ Most often in the form of voice frequency cable pairs

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SPECIAL SERVICES

Introduction

Although our next subject in discussing the DCS unit is segregation, it may help first to review special services, commonly referred to as "specials." Special services are voice, video and data circuits which require special attention in one or all of the following:

- ✔ Special engineering design features
- ✔ Special equipment requirements
- ✔ Special maintenance procedures
- ✔ Special tool requirements

POTS VS. SPECIALS

POTS

POTS, or Plain Old Telephone Service, is that portion of the network which provides service to residential and non-PBX type stations (such as in a small business), most often in the form of voice frequency cable pairs. These stations require no special attention. These types of stations are connected to a local serving Central Office through the local loop.

Special Services

Special services are communications/data services utilized primarily by business and government customers. Generally, these circuits require unique engineering/equipment design, and special maintenance procedures.

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Types of Special Services

- ✔ Voice circuits - specially designed facilities such as PBX, Centrex, Foreign Exchange
- ✔ Data circuits - communications between equipment, such as bank services and airline reservation services
- ✔ Other circuits - control circuits such as burglar/fire alarms, and broadcast circuits such as video transmission
- ✔ Critical circuits - for national security or emergency preparedness

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TYPES OF SPECIAL SERVICE CIRCUITS

Advantages These are circuits which provide person-to-person communication over specially-designed facilities. Some examples of these circuits are as follows: PBX (Private Branch Exchanges), Centrex, Foreign Exchange (FX), air-to-ground facilities (FAA), and ship-to-shore radio.

Data Circuits Data circuits allow communications between equipment, such as computers. Some examples of specific data circuits would be FAA airline tracking, bank services and airline reservation services.

Other Circuits Other types of circuits include control circuits, which provide remote monitoring and/or control of equipment such as burglar/intrusion alarms, and temperature control/monitoring; and broadcast circuits, which provide audio and video transmission for television and radio programming.

Critical Services Some special services are considered to be critical because of the importance of the service they provide. These services are provided to both government and business customers. The FCC designates four categories of circuits that qualify as national security or emergency preparedness communications.

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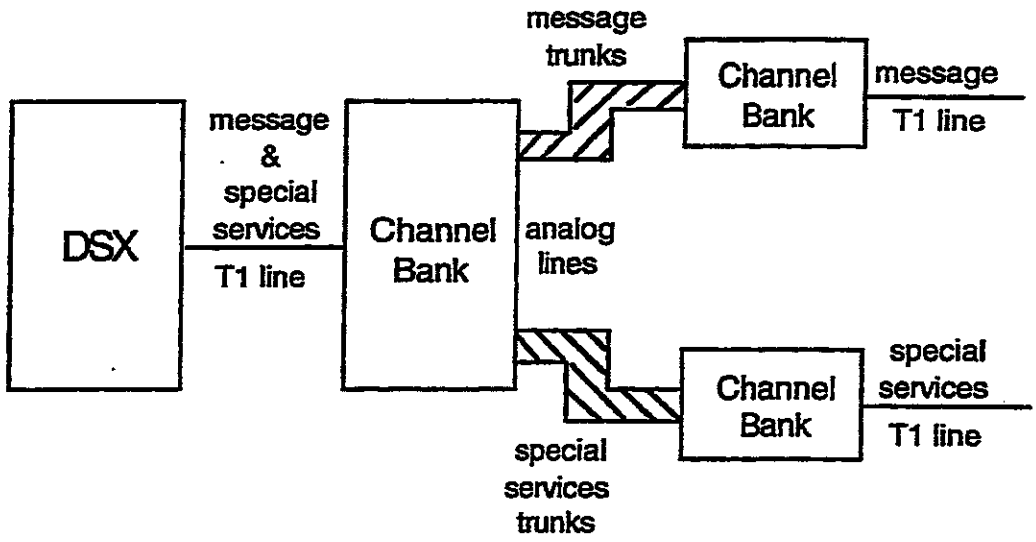
Grooming with Channel Banks



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RECONFIGURATION - SEGREGATION, OR GROOMING

Segregation

One of the features of a DCS unit is that of segregation, also referred to as grooming, which is the separation of different types of circuits on a carrier line onto other carrier lines that specialize in a particular type of circuit. Traditionally, this has been accomplished through the use of Channel Banks and a DSX cross-connect frame, as shown in the illustration. A DCS will perform the same function electronically.

Without DCS

Without a DCS, T1 lines must be converted to analog signals via Channel Banks, then physically routed on a cross-connect frame. During this process, trunks must be manually and individually tested to ensure that each step is performed correctly, and facilities must sometimes be duplicated. The costs associated with these procedures can be substantially reduced by using a DCS.

Grooming Out

Urban and suburban Central Offices typically mix message trunks and special services on the same carrier facilities. These facilities require that the special services be "groomed out" to a separate facility for interoffice routing. The facilities to the message switch can then be refilled with message circuits from other facilities.

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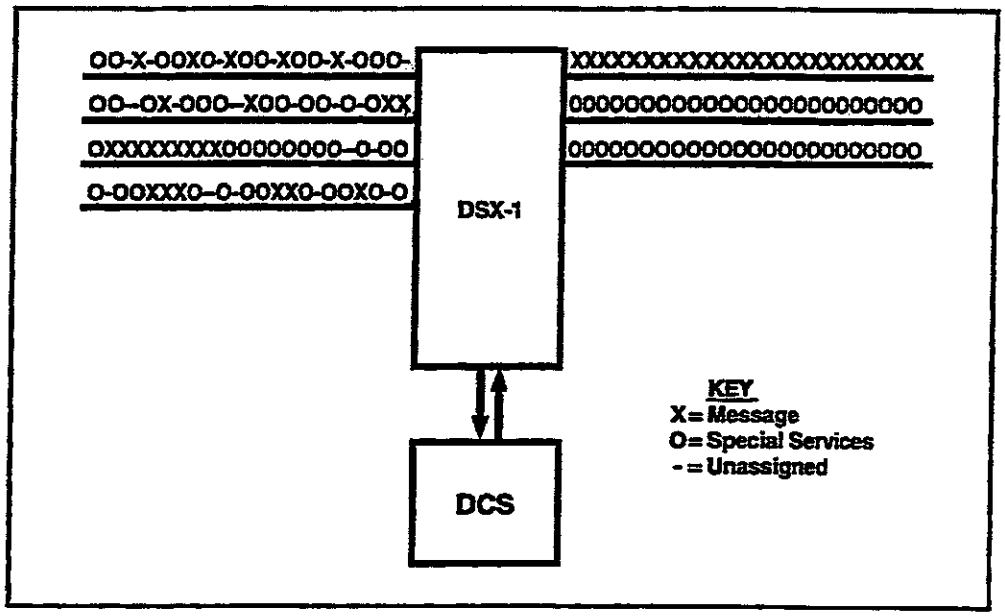
Grooming/Segregation with DCS



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RECONFIGURATION - SEGREGATION/GROOMING, continued

Segregation

Segregation with a DCS is done when a DS1 line from a distant location contains a mixture of traditional message (POTS) services and special services. The DS1 signal terminating on the DCS can be split apart into DS0 components, feeding the message portion to the Central Office switch while dropping off the special services for separate treatment or extension.

In the picture, four carrier systems are coming into the Central Office. Let's assume for a moment that the four systems are carrying voice message circuits which need to go to the switch.

There are also special service circuits which need to go to the Special Services center. In addition, there are some spare, or unassigned, channels. By using the DCS, we can cross-connect all the message circuits into a system headed for the switch. Then, all the special service circuits are connected to the Special Services center.

Without DCS

Could we have done this without the DCS? Yes, but in this case, it would have taken seven Channel Banks, and 72 frame jumpers.

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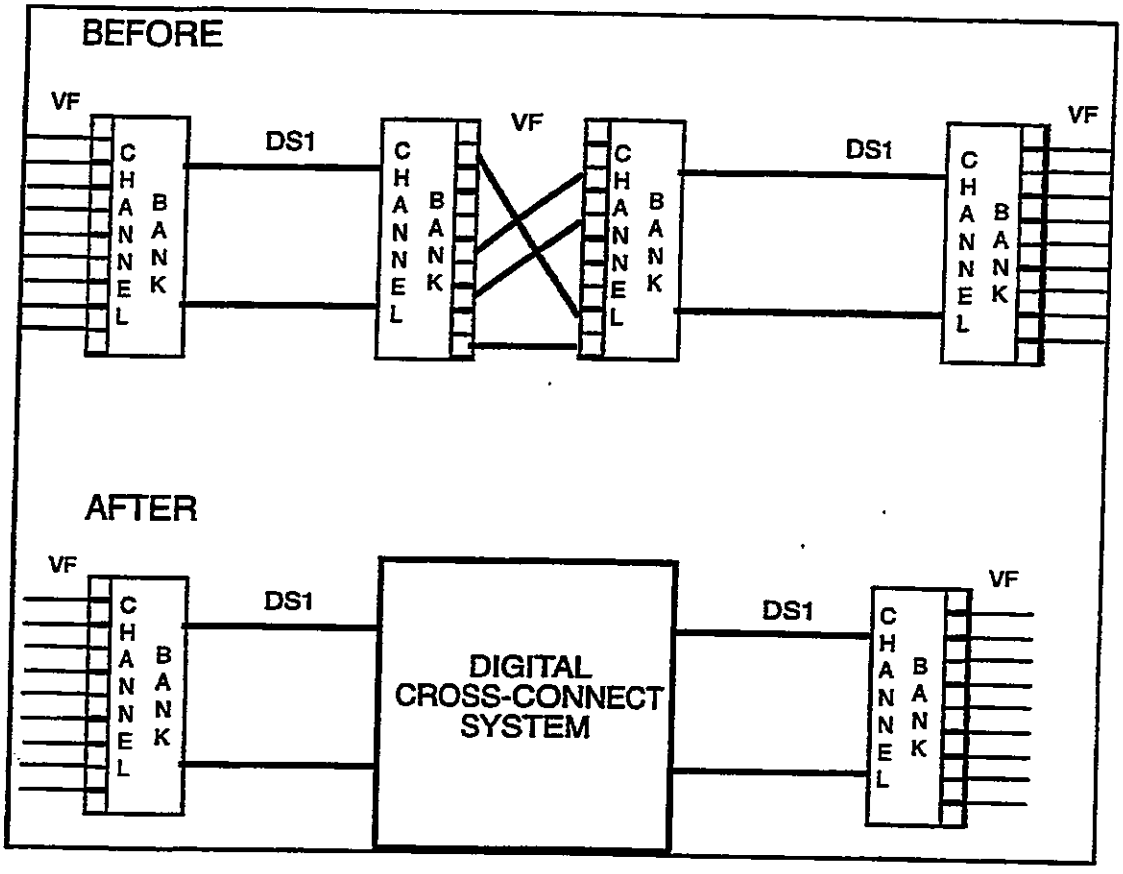
Back-to-back Channel Bank replacement



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RECONFIGURATION - CHANNEL BANK REPLACEMENT

Channel Bank Replacement

Another example of reconfiguration is the replacement of back-to-back Channel Banks. This is the essence of a digital cross-connect system.

As shown in the illustration, using a digital cross-connect system allows the channels to be redirected without being demultiplexed.

Results

By replacing back-to-back Channel Banks:

- ★ Digital-to-analog-to-digital conversions are eliminated and the integrity of the signal is maintained.
- ★ Intermediate Distributing Frames are eliminated along with their cabling and wiring.
- ★ Operations system interfaces are centralized.
- ★ Provisioning and test access can be performed from a remote location.

The consolidation of equipment saves the cost of frames and Channel Banks, recovers physical floor space and retains more signal integrity.

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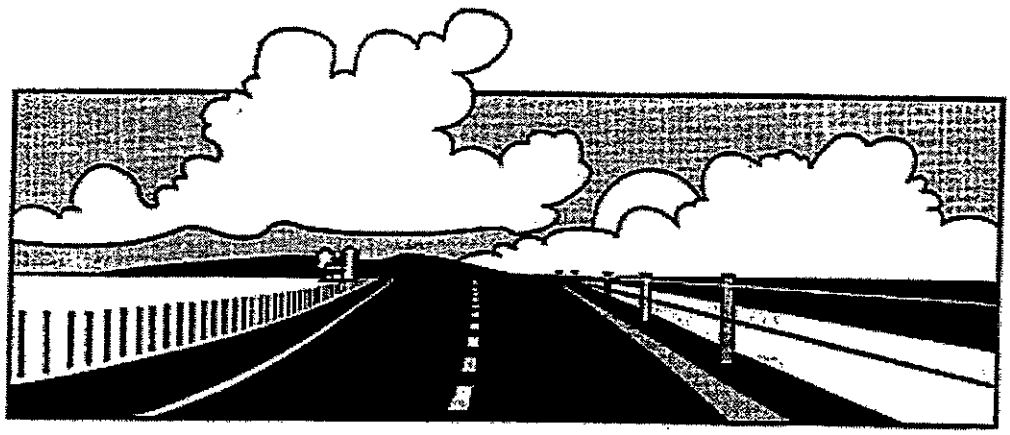

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REVIEW

1) Identify the following examples of DCS system reconfiguration.

Separates different types of circuits on a carrier line onto carrier lines that specialize in one type of circuit.

grooming

Eliminates unfilled DS0 slots from incoming DS1 lines and repackages active DS0 circuits onto fewer DS1 channels.

Concentration

Allows the channels to be reconfigured without being demultiplexed. Digital-to-analog-to-digital conversions are eliminated and the integrity of the signal is maintained.

DCS

2) List two applications of special service circuits.

data + video, digital application

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REVIEW - ANSWERS

1) Identify the following examples of DCS system reconfiguration.

Separates different types of circuits on a carrier line onto carrier lines that specialize in one type of circuit. **Segregation or grooming**

Eliminates unfilled DS0 slots from incoming DS1 lines and repackages active DS0 slots onto fewer DS1 channels. **Concentration**

Allows the channels to be redirected without being demultiplexed. Digital-to-analog-to-digital conversions are eliminated and the integrity of the signal is maintained. **Back-to-back Channel Bank replacement**

2) List two applications of special service circuits. **Any two: voice circuits; data circuits; other circuits; critical services**

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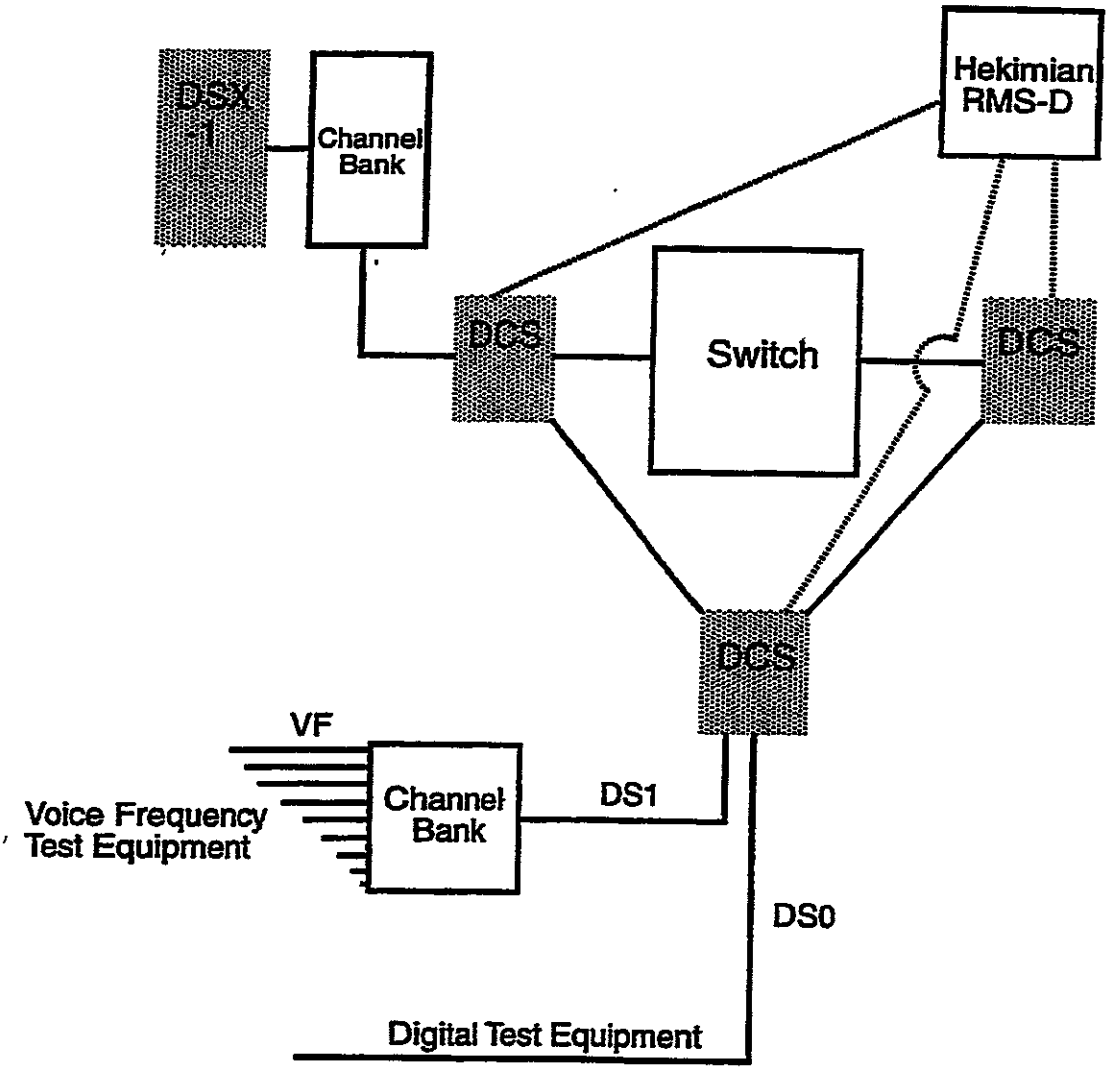
DCS Access and Testing



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DCS - ACCESS AND TESTING

DCS Testing

Access and testing are major benefits of the DCS. Any channel can be brought to a test port quickly and efficiently.

Remote Access

Remote access means that the DCS can be accessed from a remote test center anywhere in the region, using one of the remote test systems.

Examples of remote systems employed today are as follows:

- Hekimian
- Remote Maintenance System-Digital (RMS-D)

Tests

Test equipment can be engaged via a processor and the proper tests can be made by a technician from a remote area. Each of the remote test vehicles access a DCS through a processor located in key areas within U S WEST.

At the central DCS, a technician can choose to test the circuit through a Channel Bank for VF analog tests or go directly to other digital test equipment. The tester also has the option to test the circuit in the opposite direction by accessing another DCS.

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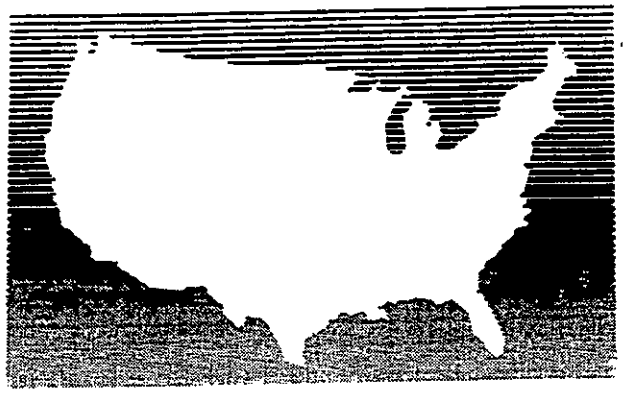

By using the DCS unit's cross-connect capability, teamed with a test access unit and a specially equipped Channel Bank, a technician can test any circuit that appears in the DCS unit.

A remotely-located tester can test lines thousands of miles away.

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DCS - ACCESS AND TESTING, continued

Flexibility

Because the DCS is a software-controlled digital switching system that provides cross-connection functions, it can be programmed to change the system's connections on a dynamic basis. This flexibility is also incorporated in the test-access function, which allows the system to temporarily connect a predefined test port to any connection in the system. As a result, testing and maintenance of individual DS0 channels of the network are greatly simplified.

Testing Any Circuit

By using the DCS unit's cross-connect capability, teamed with a test access unit and a specially equipped Channel Bank, a technician can test any circuit that appears in the DCS unit.

Test Configurations

Test access configurations are achieved by software requests. Our DCS tester could input a message telling the DCS to insert test equipment into the circuit; then, temporarily insert the test access unit into the circuit. At this point, the circuit could be connected to any of several other testing arrangements. When the testing is done, the DCS unit will put the circuit back into its original configuration. A remotely-located tester can test lines thousands of miles away.

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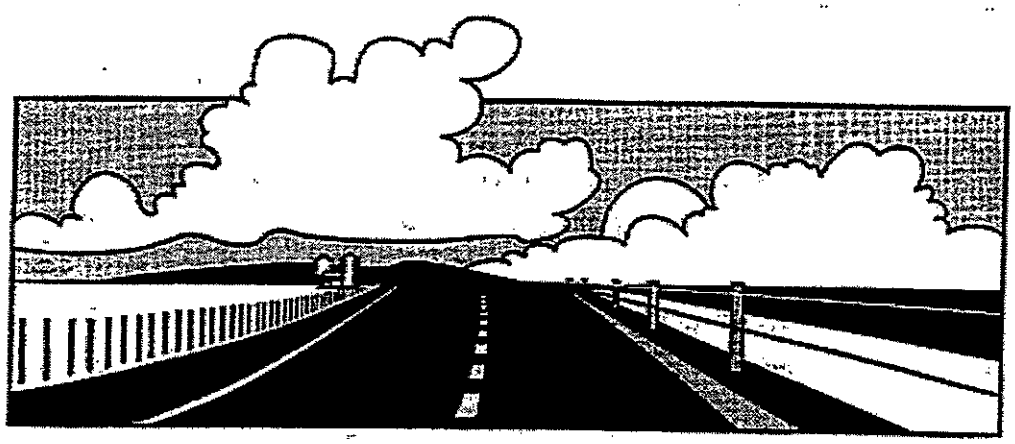

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REVIEW

1) The test access function of [redacted] allows the system to temporarily connect a predefined test port to any connection in the system.

2) Test access configurations are achieved by Software requests.

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REVIEW - ANSWERS

1) The test access function of DCS allows the system to temporarily connect a predefined **test port** to any connection in the system.

2) Test access configurations are achieved by **software** requests.

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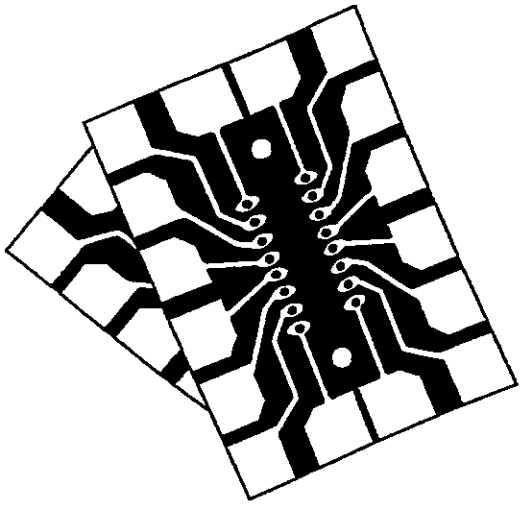

Main Components:

- ✔ The microprocessor provides the common control functions
- ✔ The microprocessor software interprets and reads out alarm conditions
- ✔ The cross-connect matrix is stored in non-volatile memory
- ✔ All critical circuits have standby circuits

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DCS -SYSTEM

The following are the main components of a DCS system.

Microprocessor The microprocessor in a DCS provides common control for the administrative functions. It contains the control, processing and memory circuitry.

Software The software in the microprocessor will interpret and read out alarm conditions within the DCS and/or the T1 lines associated with the DCS.

Non-volatile Memory All of the DCS's will have redundancy within the system. The cross-connect matrix will be stored in some type of non-volatile memory (the design depends on the vendor). A non-volatile memory means that if the power to that circuit should fail, the information within the memory would not be lost.

Critical Circuits All critical circuits in the DCS have a standby circuit to switch to if the primary circuit should fail. The monitoring and the switching of these critical circuits are controlled by the microprocessor.

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DCS Components:

- Microprocessor
- Sychronization devices
- Digital matrix
- Communication links
- Back-up memory
- Interfaces

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COMPONENTS OF A GENERIC DCS

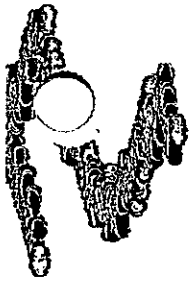
Components

Now let's consider the components of a generic DCS in a little more detail.

- Microprocessor
- Sychronization Devices
- Digital Matrix
- Communication Links
- Back-up Memory
- Interfaces

Microprocessor

The microprocessor contains the control, processing and memory circuitry to produce the programmed response to input commands, to maintain the DCS functions, and to detect and respond to internal error or alarms.



Sychronization

The sychronization devices ensure that the DCS is correctly timed to the network.

Digital Matrix

The digital matrix is where the digital cross-connects are made, under the control of the microprocessor.

Communication Links

The communication links provide the paths for the processor to communicate with other components.

Back-up Memory

The microprocessor contains the memory in which the cross-connect information is kept. There is a back-up memory in conjunction with the processor that stores all of the cross-connect information and keeps it even if there is a power failure.

Interfaces

The interfaces provide the means for the different signal paths to enter the DCS for processing.

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DCS - input/output commands:

- Connection commands
- Test access
- Facility monitoring
- Diagnostics
- Utilities commands

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DCS - INPUT/OUTPUR COMMANDS

The input/output commands for the DCS's vary slightly with each vendor, however, there are many similarities in the command structure. The following are examples of DCS commands.

Connection Commands	These commands set up or remove connections between the DS0 channels of various digroups. As you know, a digroup is 24 channels. They can apply to either individual channels, or sequential groups of channels, and can place the connections into service immediately or leave them terminated.
Test Access	These commands define test ports, select the test-port configuration, and make or remove test connections.
Facility Monitoring	These commands perform such functions as requesting maintenance information on individual digroups or for all digroups terminated on the DCS.
Diagnostics	These commands perform in-service and out-of-service circuit tests.
Utilities Commands	These commands request status reports on facility performance and system status, and perform other specified tasks.

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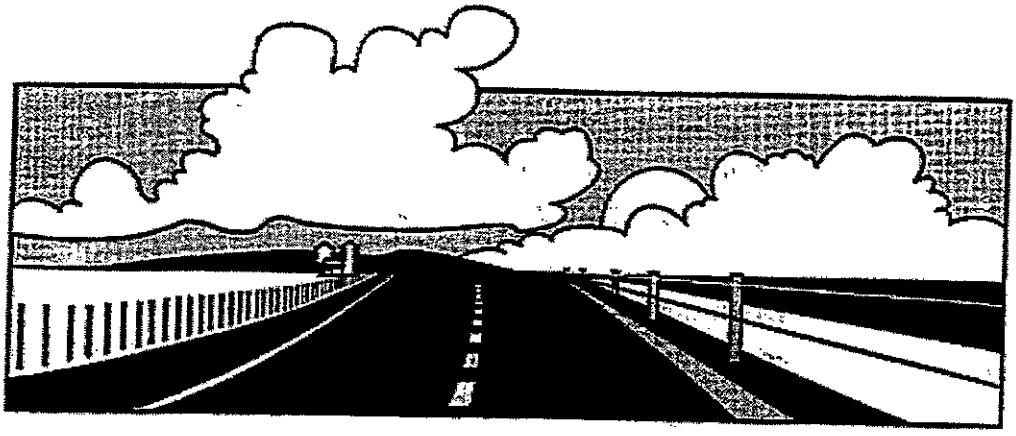

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REVIEW

1) Match the term for the DCS component with its description.

Non-volatile memory b
Interfaces d
Mircroprocessor a
Critical circuits c

a) Contains the control, processing and memory circuitry to produce the programmed response to commands.
b) Stores the cross-connect information and keeps it even if there's a power failure.
c) Provides a standby circuit that can be switched to in case the primary circuits fail.
d) Provides the means for different signal paths to enter the DCS for processing.

2) Match the input/output command with its description.

Utilities commands f
Facility monitoring e
Test access d
Connection commands b

a) Request status reports on facility performance and system status.
b) Set up or remove connections between the DS0 channels of various digroups.
c) Request maintenance information on individual digroups or all digroups
d) Define test ports, select the test port configuration, and make and remove test connections.

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REVIEW - ANSWERS

1) Match the term for the DCS component with its description.
Non-volatile memory **(b)**
Interfaces **(d)**
Microprocessor **(a)**
Critical circuits **(c)**

2) Match the input/output command with its description.
Utilities commands **(a)**
Facility monitoring **(c)**
Test access **(d)**
Connection commands **(b)**

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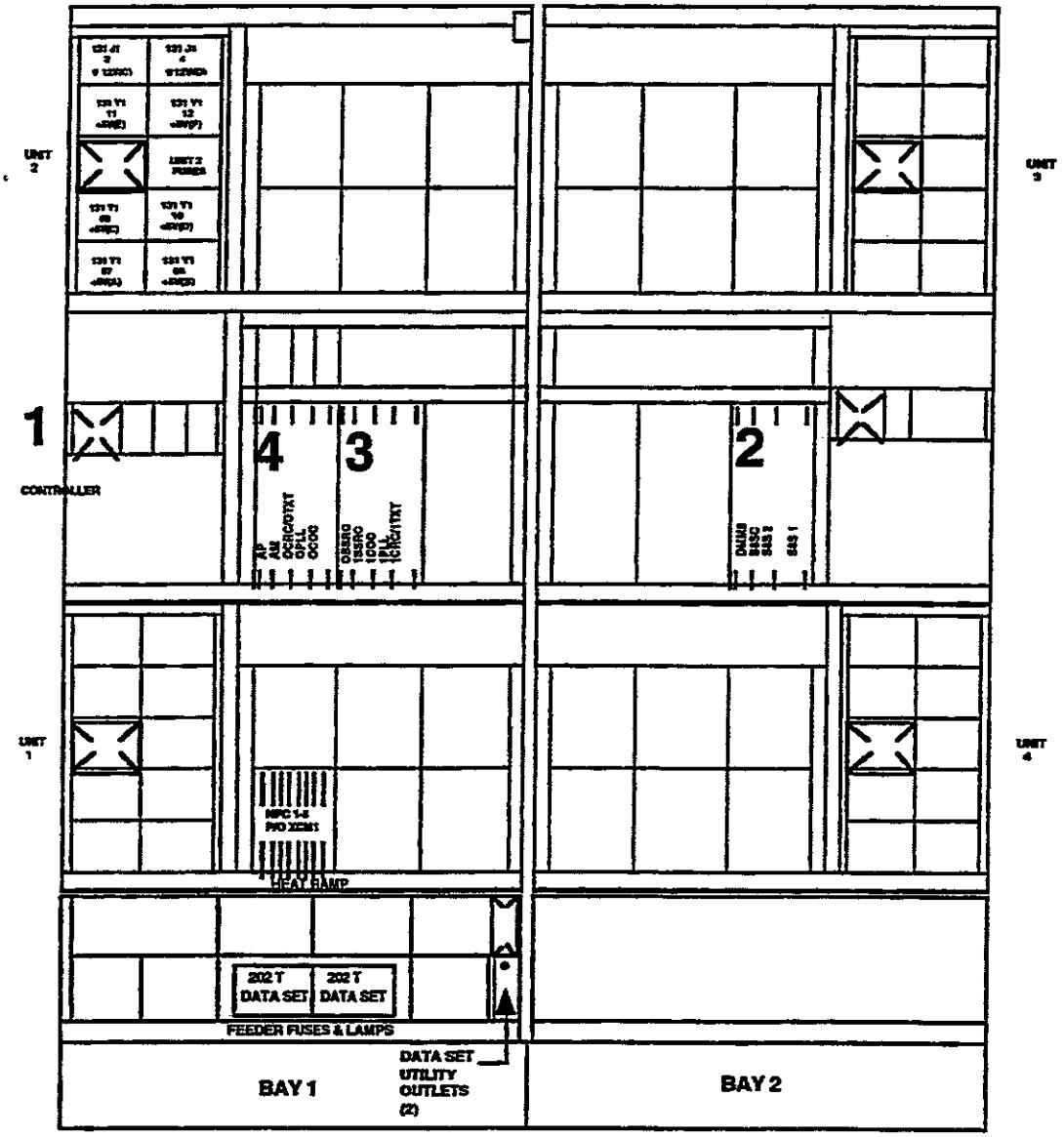
AT&T's DACS



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DCS VENDORS

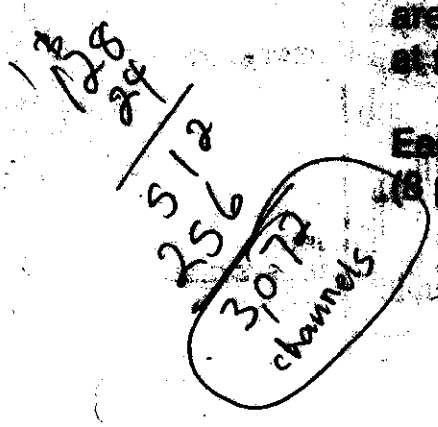
Three examples of DCS vendors we will briefly look at are AT&T's DACS, TELLABS 532 TCS, and Digital Switch Corporation's DEX CS1.

AT&T DACS

AT&T's DACS is represented at left. The controller (the central processing unit) consists of the microprocessor (labeled (1)), nonvolatile memory for backup data (2); sychronizer units (3); alarms (4).

There are four cross-connect modules or units. There are a total of 512 digroups. The digroups are the point at which the channels are cross-connected.

Each unit contains common boards, dual multiplexers (8 per unit), and digroups (32 per unit).



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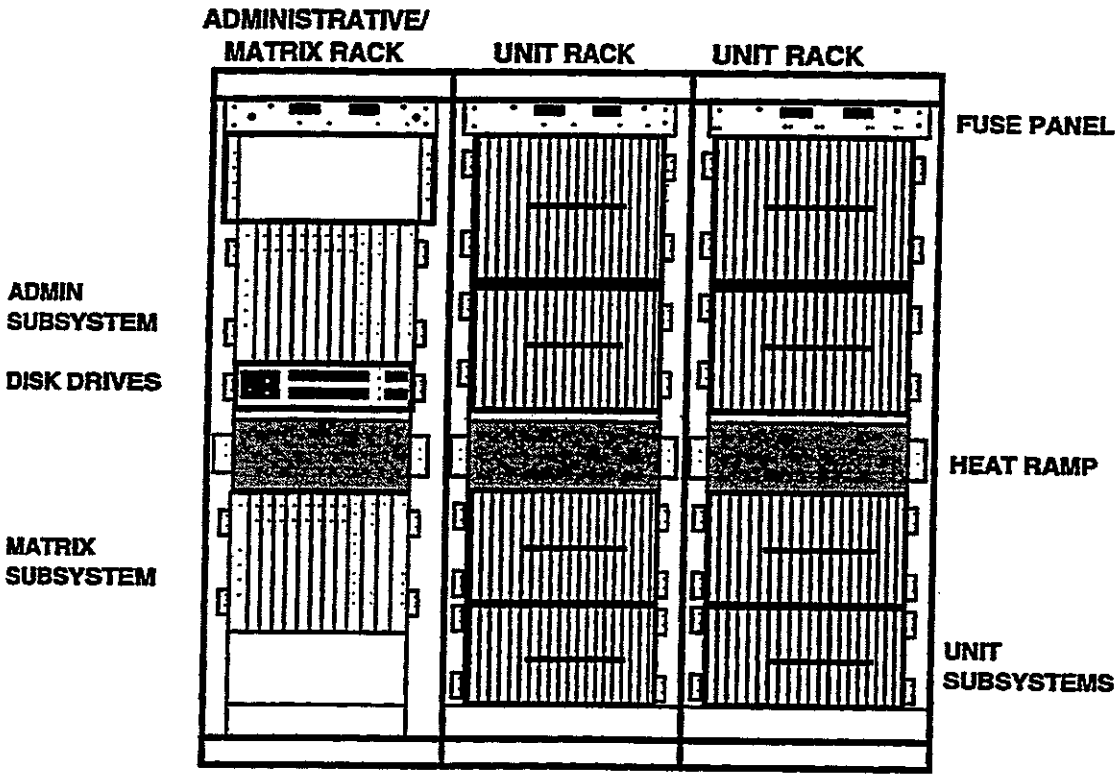
DEX CS1 Frame Layout



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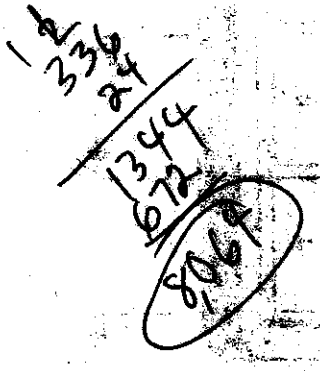
DEX CS1 DCS

The illustration shows a Digital Switch Corporation's DEX CS1 DCS. It can terminate up to 336 DS1 ports.

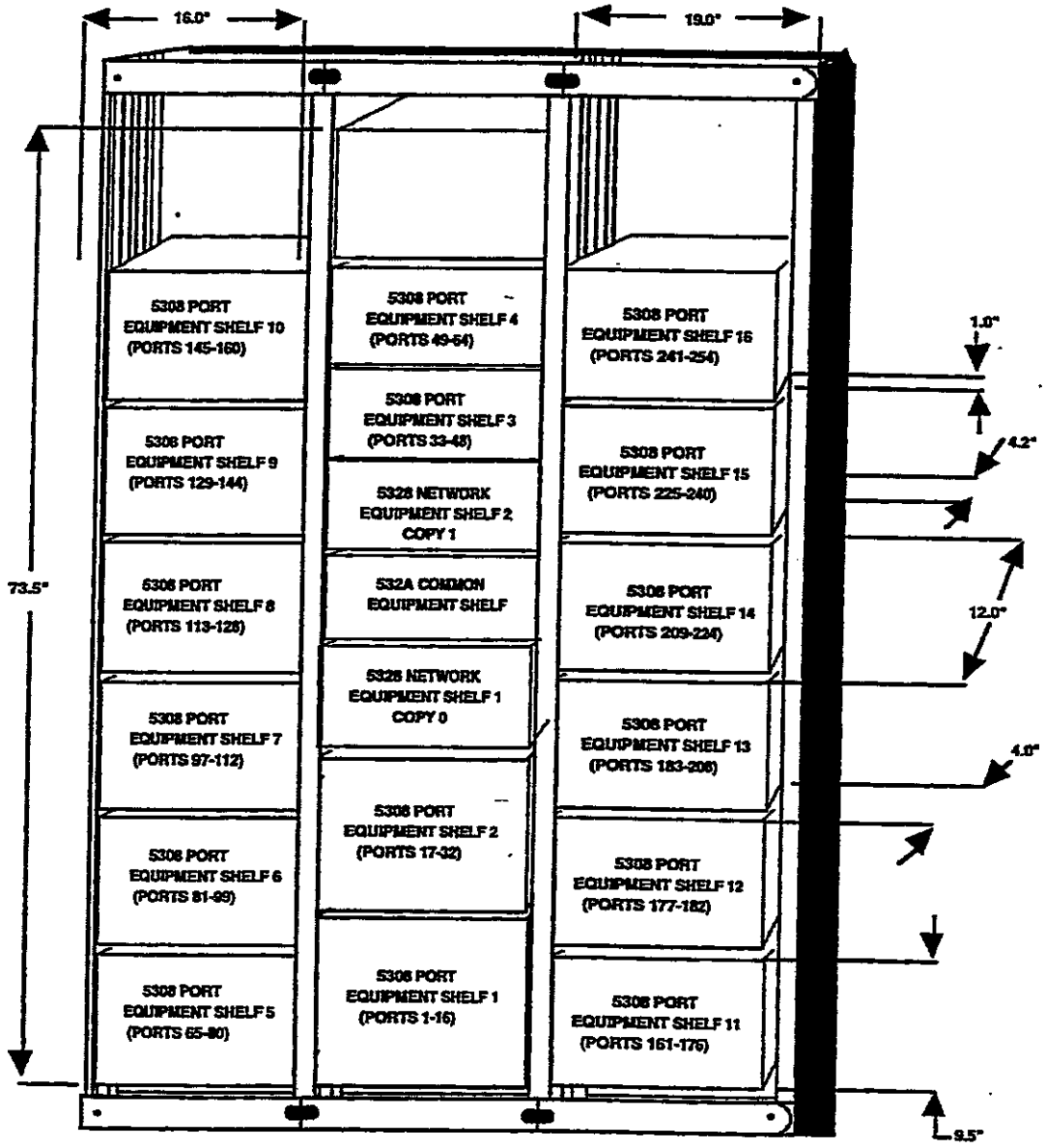
Administrative Subsystem The Administrative Subsystem provides common control for the [illegible] by providing facilities such as the microprocessor, communication interfaces, alarm interfaces, the [illegible] controller and disk drive shelf, and the power supply.

Matrix Subsytem The Matrix Subsystem provides the cross-connect paths. A single channel can be connected to any other channel or combination, or a DS1 port can be connected to any other DS1 port.

Unit Subsystem The Unit Subsystem provides the termination points for the digital lines.



Tellabs Frame Layout


16.0"
19.0"
73.5"
5308 PORT EQUIPMENT SHELF 10 (PORTS 145-160)
5308 PORT EQUIPMENT SHELF 9 (PORTS 129-144)
5308 PORT EQUIPMENT SHELF 8 (PORTS 113-128)
5308 PORT EQUIPMENT SHELF 7 (PORTS 97-112)
5308 PORT EQUIPMENT SHELF 6 (PORTS 81-96)
5308 PORT EQUIPMENT SHELF 5 (PORTS 65-80)
5308 PORT EQUIPMENT SHELF 4 (PORTS 49-64)
5308 PORT EQUIPMENT SHELF 3 (PORTS 33-48)
5328 NETWORK EQUIPMENT SHELF 2 COPY 1
532A COMMON EQUIPMENT SHELF
5328 NETWORK EQUIPMENT SHELF 1 COPY 0
5308 PORT EQUIPMENT SHELF 2 (PORTS 17-32)
5308 PORT EQUIPMENT SHELF 1 (PORTS 1-16)
5308 PORT EQUIPMENT SHELF 16 (PORTS 241-254)
5308 PORT EQUIPMENT SHELF 15 (PORTS 225-240)
5308 PORT EQUIPMENT SHELF 14 (PORTS 209-224)
5308 PORT EQUIPMENT SHELF 13 (PORTS 193-208)
5308 PORT EQUIPMENT SHELF 12 (PORTS 177-192)
5308 PORT EQUIPMENT SHELF 11 (PORTS 161-176)
1.0"
4.2"
12.0"
4.0"
9.5"

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TELLABS 532 TCS

We'll conclude our brief look at examples of DCS frames with an overview of the Tellabs' 532 TCS, illustrated at left.

Frame

The frame has one common equipment shelf and two network equipment shelves. These shelves contain the frame microprocessor, common power, frame memory, etc.

The remaining shelves contain the actual ports. In this illustration, 16 shelves house a total of 256 ports.

Each vendor's frame is configured in a different manner. However, the frames serve the same function - allowing digital cross-connects.

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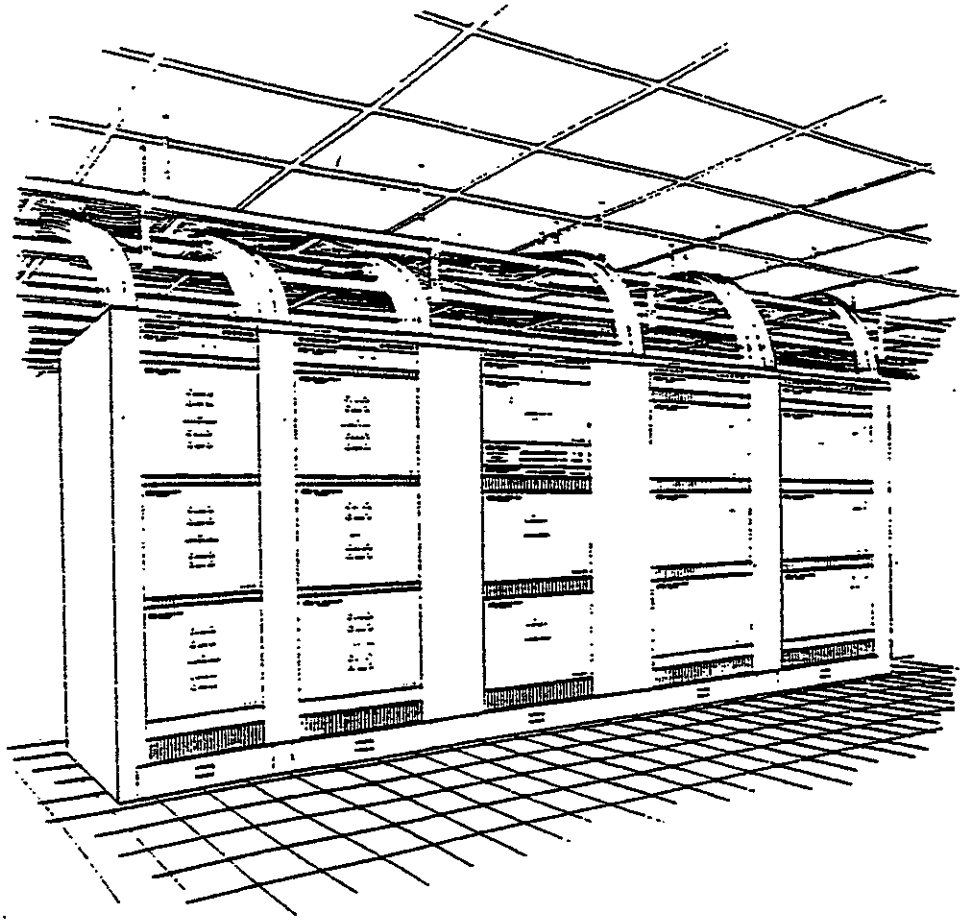
EDSX



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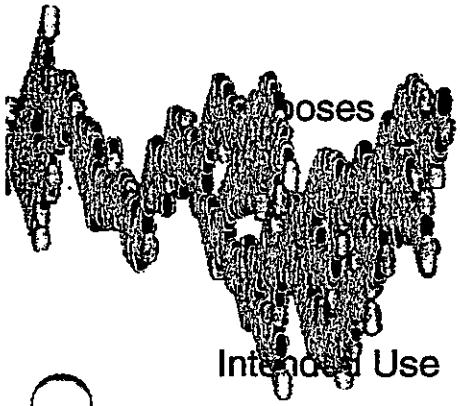
DIGITAL CROSS-CONNECT SYSTEMS - FURTHER DEVELOPMENTS

EDSX

A recent innovation is the Electronic DSX (EDSX) frame. The EDSX is a software-driven device that will do the same functions as the manual DSX. The EDSX can accommodate DS1, DS1C, DS2, DS3 and fiber-optic digital signals.

Like the DSX, the EDSX terminates and cross-connects digital signals at a given bit rate without processing signals lower than a DS1.



The principle purposes of the EDSX are:

- ✔ To provide cross-connects
- ✔ To provide test access
- ✔ To provide rearrangements

Intended Use

The EDSX is intended to replace the functions of the manual DSX. An EDSX, electronically controlled via a local or remote user system interface or remote operations system, will allow much faster and less expensive rearrangements than a DSX.

Test Access

The EDSX has test access capability, much like the DCS. Access can be done either locally or remotely. An EDSX activates local and remote alarms when EDSX equipment failures are detected.

Memory Administration

The Memory Administration function of the EDSX allows storage and manipulation of data that can be stored in the EDSX's memory. This allows the addition of new digital signal terminations and the cross-connection of existing terminations.

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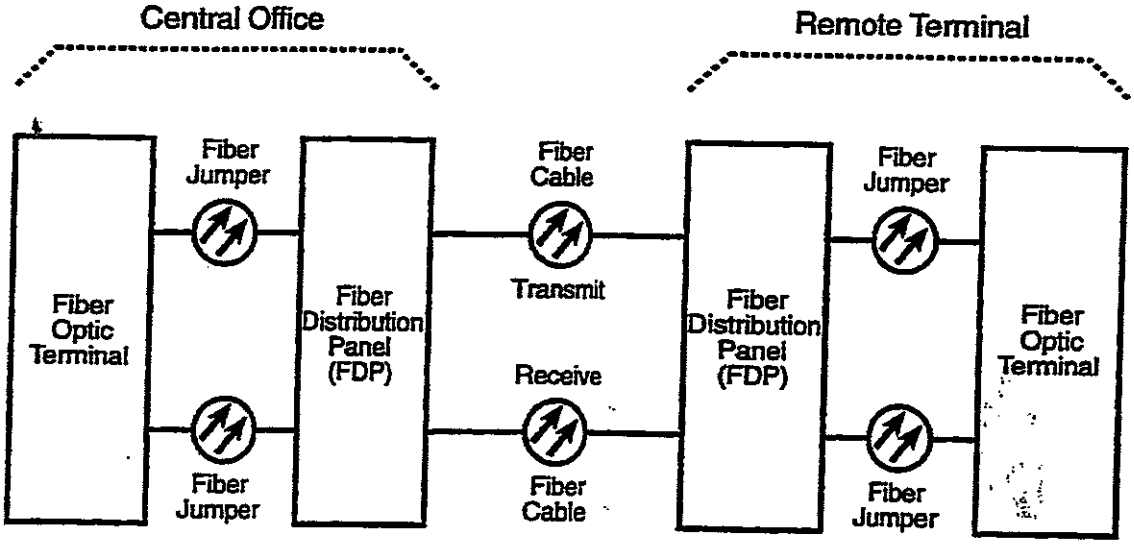
Digital Fiber Optic Transmission System



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FIBER DISTRIBUTION PANEL

The Fiber Distribution Panel (FDP) has two main functions. They are:

- To provide the interface between outside plant fiber cables and fiber jumpers to the Fiber Optic Terminal equipment (or other outside plant cables), and
- To permit rapid fiber cross-connections, rearrangements, maintenance, testing, and system growth.

Alarms

The Fiber Distribution Panel also does not have alarms; it is for cross-connecting fiber optic systems. Alarms would be on the Fiber Optic Terminal or carrier on each side. The FDP is the counterpart of the DSX panels discussed earlier.

The FDP provides:

- A convenient interface between outside plant and Central Office responsibilities.
- A means for centralized access to the fibers in the outside plant cables.
- An interface between optical transmission equipment and the fiber transmission path.
- Cable termination for outside plant fiber cables or building riser cables.
- Physical security and organization for fiber splices, connection, and fiber slack.

The FDP is located in the transmission system between the Fiber Optic Terminal and outside plant. The connections between the Fiber Optic Terminal and the FDP are made by separate fibers called fiber jumpers.

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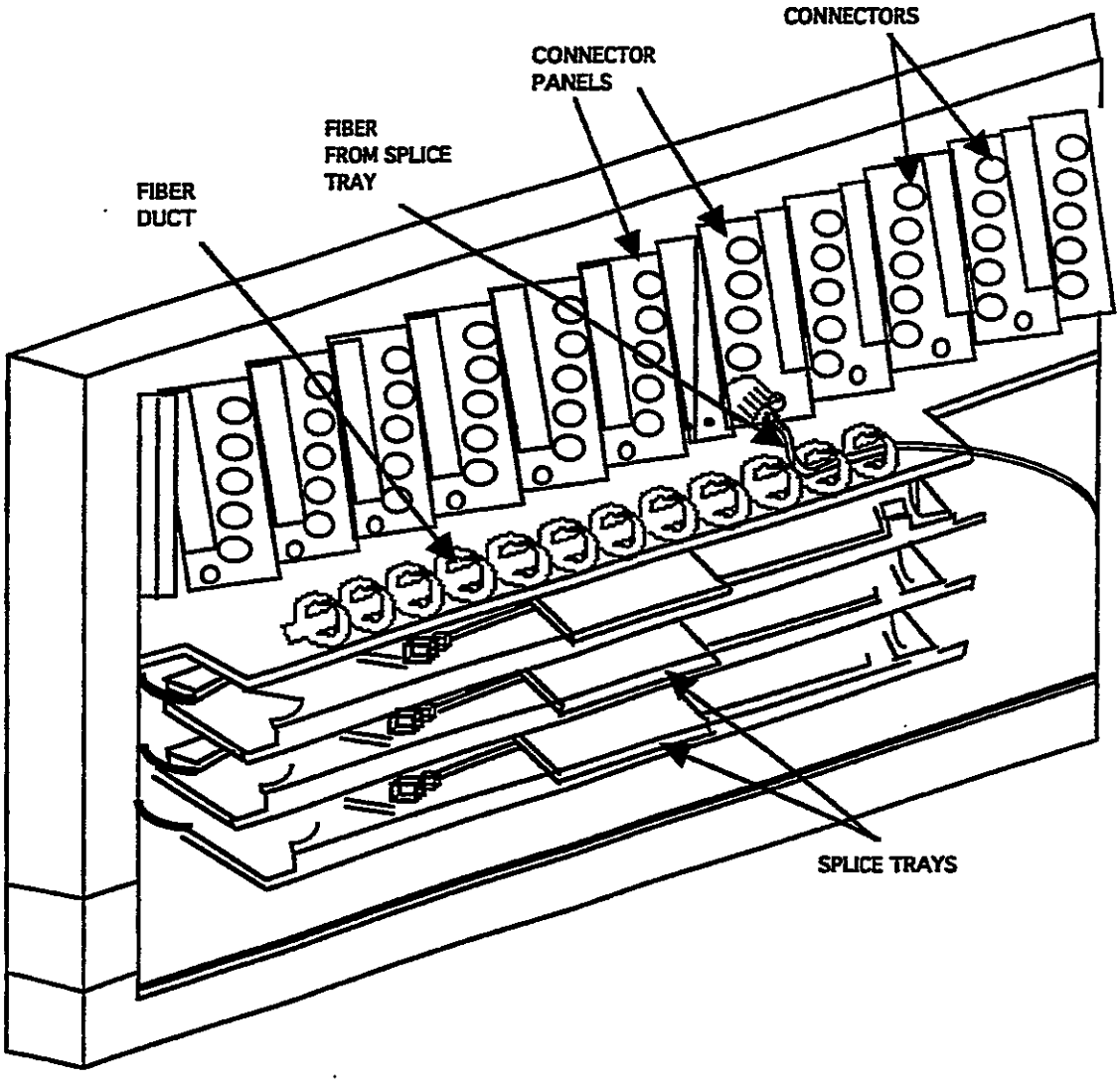
Fiber Distribution Panel



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FIBER DISTRIBUTION PANEL, continued

C.O. Application

In a Central Office application, aisle space is provided in front and back of the bay. Normally all interconnects and activities such as rearrangements, tests, etc. are done from the front. The rear of the bay is used for riser cable termination, splicing, and fiber connection.

Remote

In most cases, for remote installations (such as mini-huts and Controlled Environmental Vaults) all cable terminating, splicing, and maintenance is done from the front.

The connector panels are hinged and swing out to allow access to the rear of the panels for outside plant fiber cable connection.

FDP Connections

Shown is an example of the front of an FDP Equipment connections are made with fiber jumper cables to the front of the connector panel. The fiber jumpers are measured to length with about 2 feet of slack at the FDP and fitted with the appropriate connectors. Note that the connector panels have groups of connectors mounted on them. These connectors match to the connectors on the end of the fiber jumpers coming from the Fiber Optic Terminal. The types of connectors used may differ from vendor to vendor.

A splice tray, or slack tray, is located below the connector panel in our example. A fiber duct is provided for both neatness and protection of the fiber jumper.

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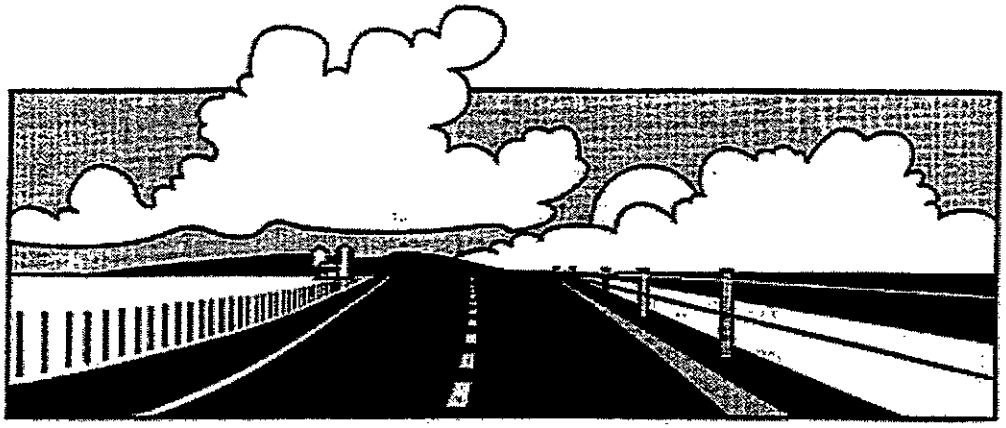

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REVIEW

1) Indicate whether the following statements about the EDSX are true or false.

J Provides test access.
J Electronically controlled via a local or remote interface.
J Can process signals lower than a DS1.
J Data can be stored and manipulated

2) Indicate whether the following statements about the Fiber Distribution Panel (FDP) are true or false.

J It is the equivalent of the DCS.
J It is not equipped for alarms.
J It provides access between the Fiber Optic Terminal and the fiber optic transmission cable.
___ Interconnect arrangements and testing is done at the rear of the FDP.

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REVIEW - ANSWERS

1) Indicate whether the following statements about the EDSX are true or false.

True Provides test access.
True Electronically controlled via a local or remote interface.
False Can process signals lower than a DS1.
True Data can be stored and manipulated

2) Indicate whether the following statements about the Fiber Distribution Panel (FDP) are true or false.

False It is the equivalent of the DCS.
True It is not equipped with alarms.
True It provides an interface between the Fiber Optic Terminal and the fiber optic transmission cable.
False Interconnects, rearrangements and testing is done at the rear of the FDP.

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This concludes Part C

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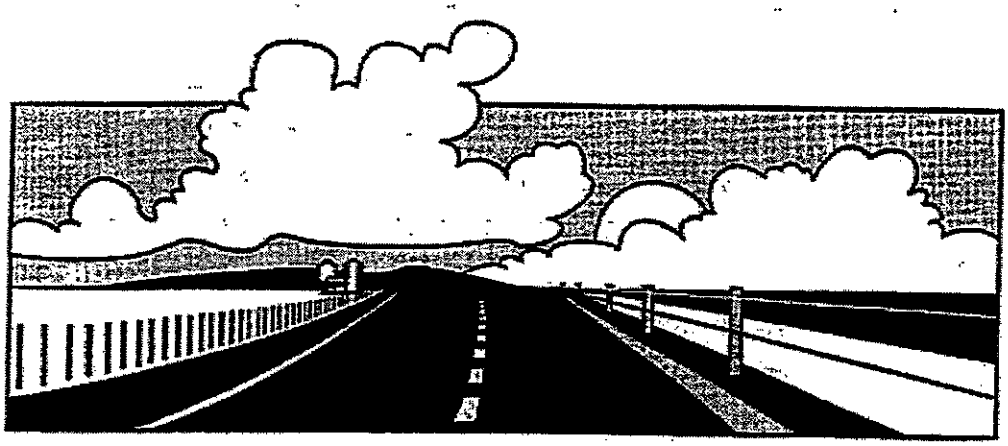

Proceed to Part D

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Table of Contents

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PART D: PAIR GAIN SYSTEMS

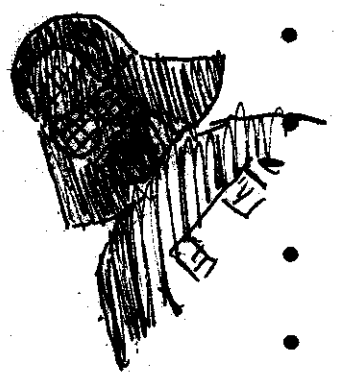
PURPOSE AND PREVIEW

Purpose

The purpose of this section is to provide you with an appreciation of the importance of pair gain systems, and to give you an overview of four different Digital Loop Carrier systems. More and more customers are using pair gain technology to enter the Central Office. These systems can interface directly with the switch. Knowledge of this technology is necessary for Central Office maintenance.

Preview

The following subjects are included in this section:



- Pair gain systems
- Digital Loop Carrier
- Subscriber Loop Carrier-96 (SLC-96)
- SLC-96 system components, equipment features and enclosures
- Digital Integrated Subscriber Carrier System (DISC*S)
- DISC*S system components and equipment features
- Universal Digital Channel (UDC) Miniplex System
- UDC system components and equipment features
- Digital Multiplex System-1 Urban (DMS-1 Urban)
- DMS-1 Urban system components and equipment features

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Loop Electronics:

- Electronic devices which reduce the need for wire in the local loop

Pair Gain Systems:

- Reduce the number of pairs in the loop that are required to serve subscribers
- Reduce capital costs

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PAIR GAIN SYSTEMS

To begin our discussion of pair gain systems, we will discuss loop electronics.

Loop Electronics

Loop electronics can be defined as electronic devices which reduce the need for solid wire in loop circuits extending from the Central Office to the customer's telephone set.

Pair Gain Systems

Pair gain systems are loop electronic systems that reduce the number of pairs in the loop that are required to serve a given number of subscribers.

The basic objective of the use of loop electronics is to reduce capital costs. For example, while the price of cable has been rising, the cost of electronic devices has been coming down. New technology is introducing better systems at lower prices.

Pair gain systems save dollars by reducing the number of pairs required to provide telephone service to subscribers.

With pair gain systems, many customers can be served between a Remote Terminal and a Central Office Terminal, over a small group of wires. This is accomplished through multiplexing.

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Advantages of Digital Loop Carrier:

- ✔ Reduces cable requirements
- ✔ Economical and efficient alternatives
- ✔ Useful alternative to a switching office
- ✔ Short provisioning and maintenance times, quicker response times

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DIGITAL LOOP CARRIER

Pair gain systems can be analog or digital. An example of a digital pair gain system is the Digital Loop Carrier system.

Modern Channel Bank technology led to the development of Digital Loop Carrier (DLC). DLCs are also called, interchangeably, pair gain systems or Subscriber Loop Carriers. Digital Loop Carriers connect subscribers to the Central Office.

With DLC systems, telephone services are provided by interfacing the subscriber's line with loop electronics on the end of a digital facility.

Advantages

The advantages of DLC Systems are as follows:

- ✔ Reduces the quantity of cable systems.
- ✔ Provides economical and efficient alternatives to other forms of providing service.
- ✔ Provides a useful alternative to a switching office in remote areas.
- ✔ Provides relatively short provisioning and maintenance times. Allows quicker response time to meet customer needs, such as unexpected growth from new development.

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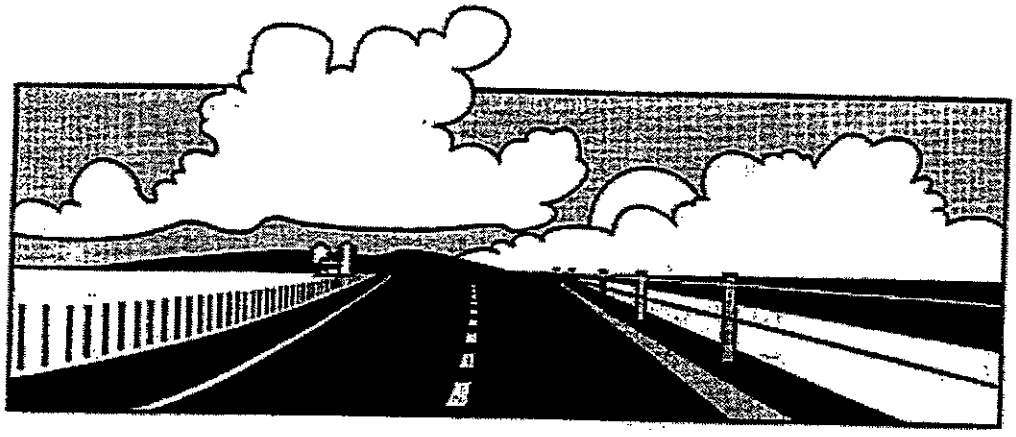

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REVIEW

1) Pair gain systems are electronic systems that reduce the number of pairs in the loop that are required to serve a given number of subscribers.

2) With pair gain systems, multiple customers are served between a Remote Terminal and the Central Office Terminal, over a single group of wires.

3) With Digital Loop Carrier systems, telephone services are provided by interfacing the subscriber lines with loop electronics on the end of a digital facility.

4) List at least one advantage of the Digital Loop Carrier system.
reduction in lots of wire runs

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REVIEW - ANSWERS

1) Pair gain systems are **electronic** systems that reduce the number of **pairs** in the loop that are required to serve a given number of subscribers.

2) With pair gain systems, multiple customers are served between a **Remote Terminal** and a Central Office **Terminal**, over a **small** group of wires.

3) With Digital Loop Carrier systems, telephone services are provided by interfacing the subscriber's line with loop **electronics** on the end of a **digital** facility.

4) List at least one advantage of a Digital Loop Carrier system. Any one of the following answers are acceptable: **reduces cable requirements; quicker response times; economical and efficient alternatives; useful alternative to a switching office; short provisioning and maintenance times**.

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Vendors of Digital Loop Carrier equipment:

- AT&T
- Reliance Comm/Tec
- Northern Telecon
- Rockwell
- Siescor

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DIGITAL LOOP CARRIER - VENDORS

Vendors of Digital Loop Carrier equipment include:

- AT&T - SLC-96
- Reliance Comm/Tec - DISC*S
- Northern Telecom - DMS-1 Urban
- Rockwell - LMS-3192
- Siescor - S24-DU

We will look at three examples of DLC equipment: the SLC-96, the DISC*S, and DMS-1 Urban.

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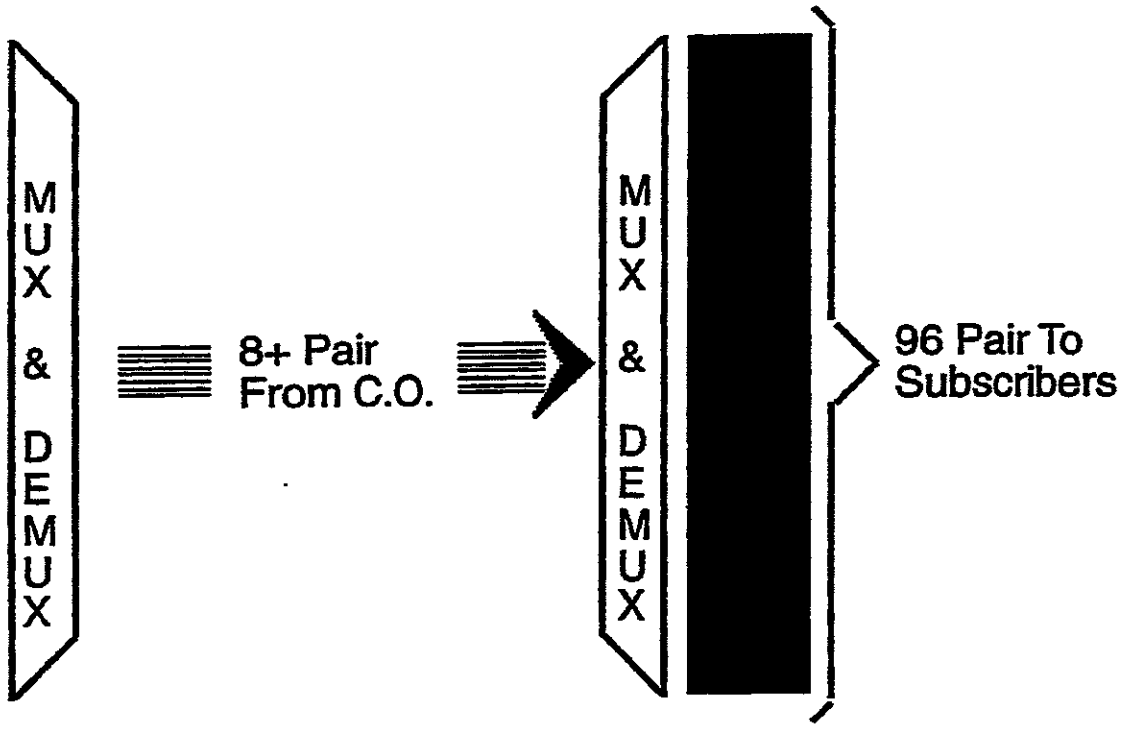
Subscriber Loop Carrier - 96



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SUBSCRIBER LOOP CARRIER-96 (SLC-96)

System

The first example of a Digital Loop Carrier we're going to look at is a system called the Subscriber Loop Carrier 96 (SLC-96), by AT&T.

A Subscriber Loop Carrier 96 (SLC-96) system combines 96 telephone conversations and transmits them over 8 cable pairs. The system uses Time Division Multiplexing to carry 24 voice channels over two pairs of wires. Two cable pairs are required for a two-way transmission line. They are called the transmit and receive cable pairs.

Two cable pairs are required for backup or protection of the 8 cable pairs used for transmission.

Use

The SLC-96 can be used in areas where there is a high impulse demand for service, followed by a slower growth rate. Some examples are as follows:

- New, large, apartment, condominium or townhouse complexes.
- New office complexes or industrial parks.

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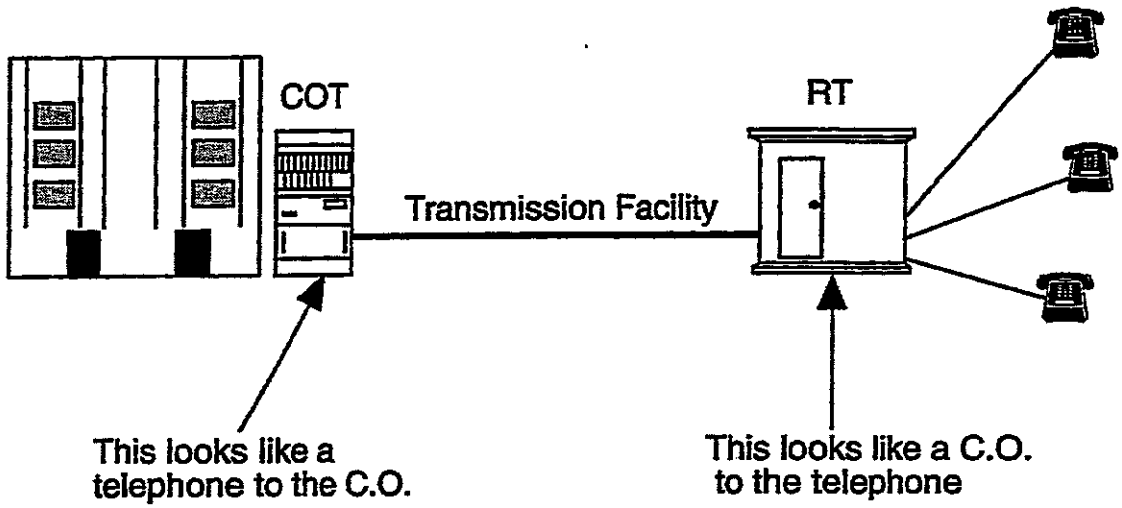
Subscriber Loop Carrier-96 System



Key:
COT = Central Office Terminal
RT = Remote Terminal

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SLC-96 - SYSTEM

System

The system requires the installation of both Central Office and remote units which perform the multiplexing and demultiplexing functions.

Components

As depicted in the graphic, the SLC-96 system consists of the following components:

- A Central Office Terminal (COT)
- A Remote Terminal (RT)
- Connecting digital carrier lines (T1 Carrier)

COT

A Central Office Terminal consists of an assembly of shelves, common equipment, plug-in units, line termination, and powering. It is physically located in the Central Office.

RT

The Remote Terminal is enclosed in a weatherproof hut or a buried vault, and contains common equipment circuitry, plug-in line units, AC power, and batteries. It is located at a remote location, anywhere in the serving area of the Central Office.

Non-integrated System

The system shown in the illustration is referred to as a non-integrated pair gain system, in that it requires a Central Office Terminal and can be used with any switching system.

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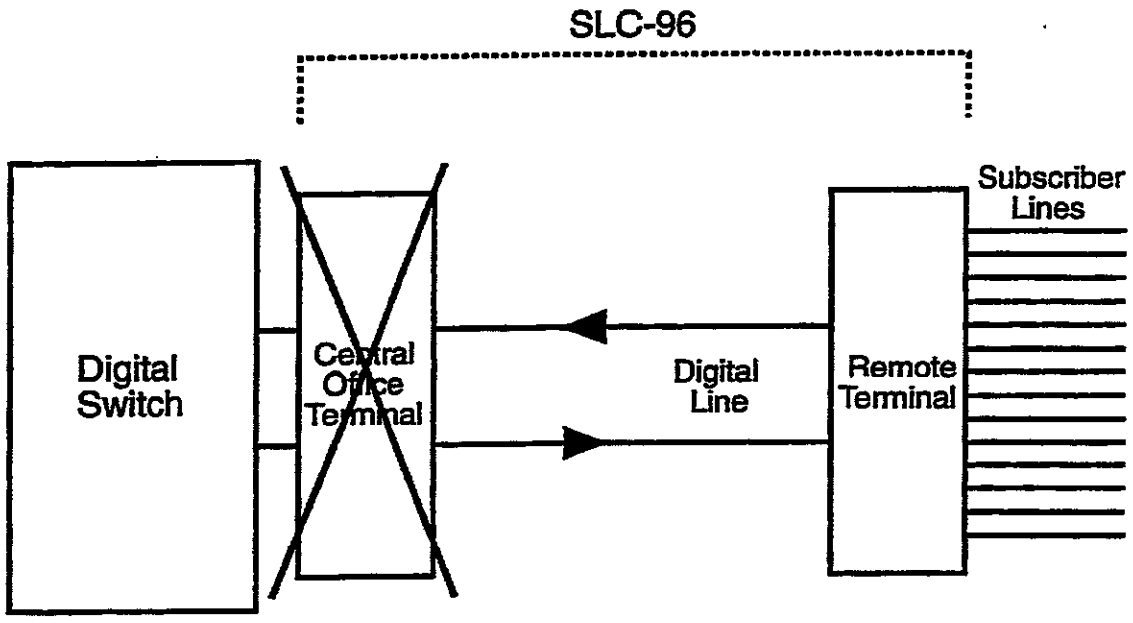
Integrated SLC-96 System



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SLC-96 SYSTEM, continued

Integrated System	An integrated pair gain system (in this case, a SLC-96) is integrated with a particular type of host digital switch (such as a 5ESS) and does not have a Central Office Terminal where individual subscriber lines reappear.

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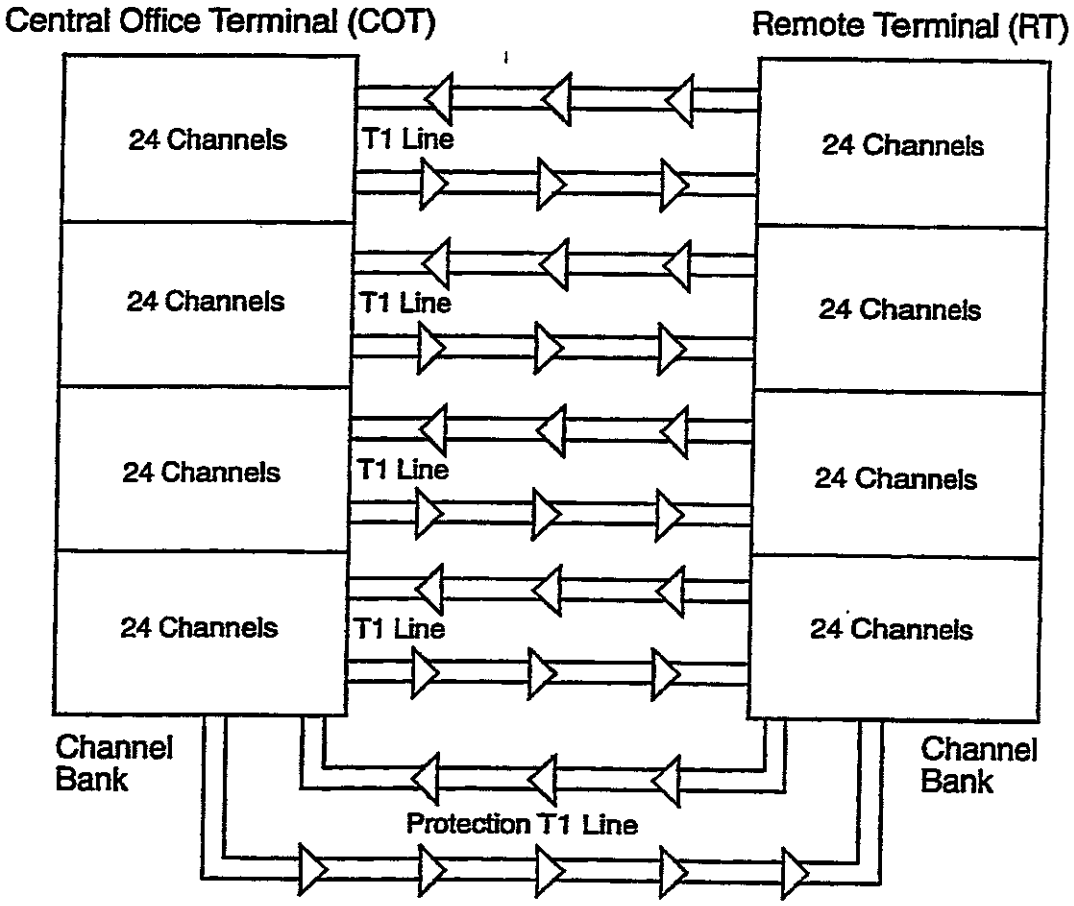
SLC-96 Carrier System



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SLC-96 - SYSTEM, continued

Channel Bank	The Channel Bank is the main unit of the SLC-96 system. It contains four shelves, each of which processes 24 channels, or subscriber lines. The entire bank is capable of processing 96 channels, hence the name, SLC-96.
Digital Lines	T1 lines connect each shelf in a COT to a corresponding shelf in an RT bank. One cable pair is used to make the transmitting connection and another is used to make the receiving connection. The combination of the "transmit" pair and its associated "receive" pair is one T1 line.
Protection Line	There is a protection line, as shown in the illustration. It is provided in the event that one of theT1 lines go down.
Operation	The basic operation of the SLC-96 Central Office Terminal and Remote Terminal is similar to that of a Channel Bank. The same three steps of analog to digital conversion are followed: sampling, quantizing, and encoding.

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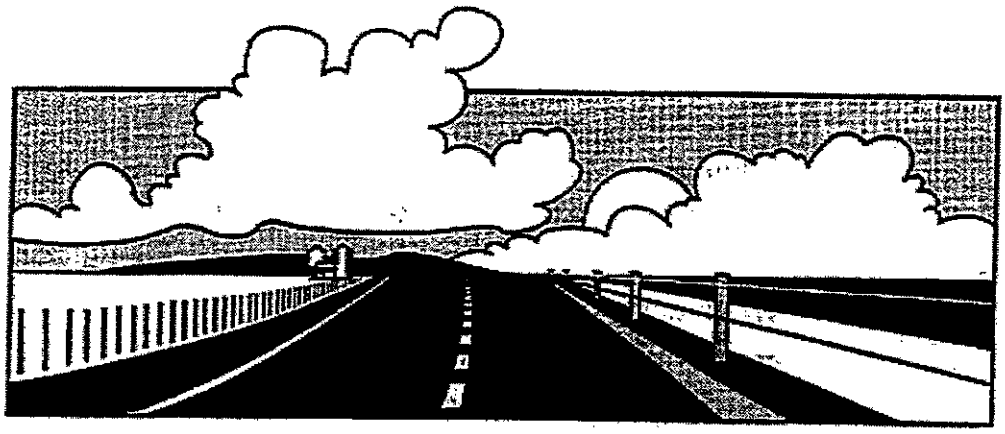

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REVIEW

1) Explain the significance of the SLC-96's name.
Supports 96 channels

2) List the three major components of a SLC-96 system.
a) Remote Terminal
b) C.O. Terminal
c) T1 lines between them

3) Explain what an integrated SLC-96 system is.
A system that is integrated into the switch.

4) The Channel Bank is the main unit of the SLC-96 system.

5) The combination of the "transmit" pair and its associated "receive" pair is one T1 line.

6) Each shelf in the SLC-96 terminal can process 24 channels.

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REVIEW - ANSWERS

1) Explain the significance of the SLC-96's name. **The system is capable of processing 96 channels.**

2) List the three major components of a SLC-96 system.
   a) **A Central Office Terminal (COT)**
   b) **A Remote Terminal (RT)**
   c) **Connecting digital carrier lines (T1 Carrier)**

3) Explain what an integrated SLC-96 system is. **An integrated SLC-96 system is integrated with a particular type of host digital switch (such as a 5ESS) and does not have a Central Office Terminal where individual subscriber lines reappear.**

4) The **Channel Bank** is the main unit of the SLC-96 system.

5) The combination of the "transmit" pair and its associated "receive" pair is one **T1** line.

6) Each shelf in the SLC-96 terminal can process **24** channels.

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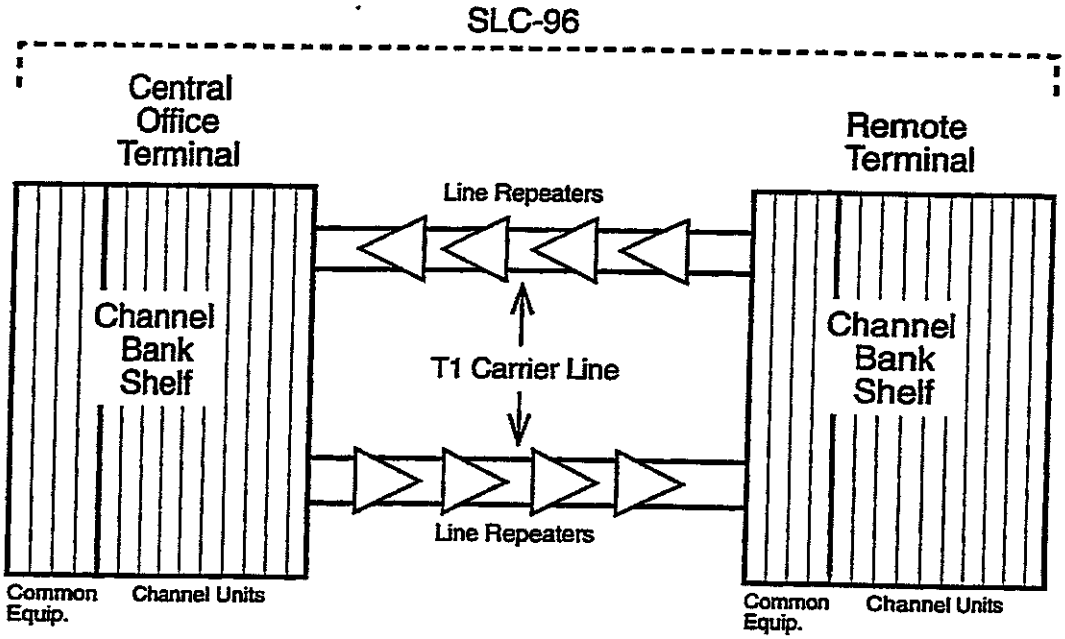

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SLC-96 - OPERATION

As with a D-type Channel Bank, a SLC-96 bank contains both Common Equipment Units and Channel Units

The four shelves house 96 SLC-96 Channel Units and 16 Common Equipment Units. The system is capable of single party, multi-party, coin and special services applications.

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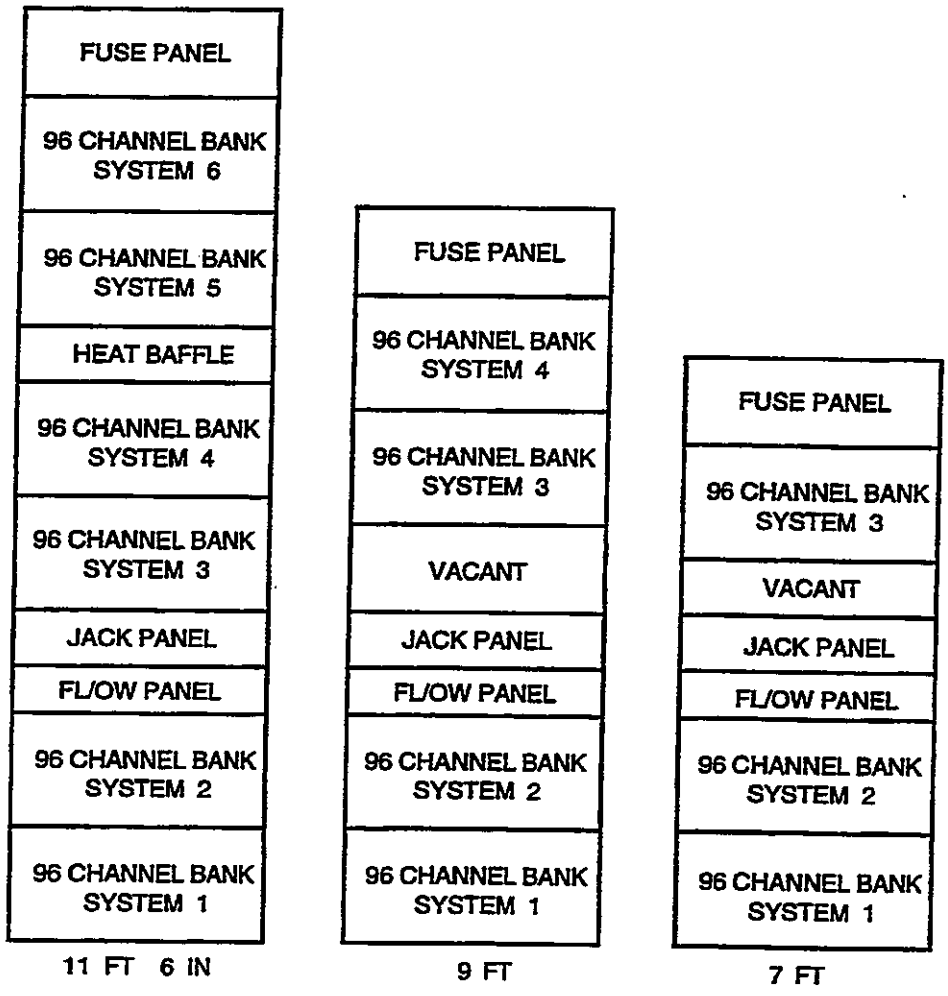
Central Office Terminal



Typical COT Full Bay Arrangements (7-Foot, 9-Foot, and 11-Foor 6-Inch Frames)

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SLC-96 - CENTRAL OFFICE TERMINAL/REMOTE TERMINAL

Central Office Terminals are configured for six Channel Banks in an 11 foot 6 inch bay, four Channel Banks in a 9 foot bay, and three Channel Banks in a 7 foot bay, as shown in the illustration. The factory wired bays are equipped with Channel Banks, fuse and alarm panel, and a jack panel.

The fuse and alarm panel distributes power to the common units. The jack panel provides a means of access to the T1 lines for testing purposes.

Each Channel Bank assembly consists of four shelves and requires 19 inches of vertical mounting space.

Remote Terminal

The SLC-96 Remote Terminal is available in a variety of arrangements to accommodate customer requirements as installation size, application, remote site requirements and environmental conditions.

The Remote Terminal is physically similar to the COT, however bay and frame mounting arrangements may vary depending on the enclosure used at the remote site. We'll look at some examples of these enclosures in a moment.

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Maintenance features of the SLC-96:

- Continuous monitoring
- Alarm displays
- Transmission of alarms
- Automatic protection switching
- Test of customer channel and loop
- Fault locating

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SLC-96 MAINTENANCE FEATURES

Maintenance

Many of the maintenance features of the SLC-96 enable telco personnel to identify and locate trouble. The following are the SLC-96 maintenance features:

- Continuous monitoring of performance characteristics involving groups of 24, 48, or 96 channels.
- Alarm displays at the Central Office Terminal and the Remote Terminal indicate system status and aid in corrective maintenance. Alarm status and displays are shown on a shelf-by-shelf basis.
- Transmission of alarms to a designated remote alarm maintenance center.
- Automatic protection switching to a protection line.
- Test of customer channel and loop beyond the Remote Terminal, remotely controlled from the test center.
- Fault locating for digital line troubles. Sectionalization features allow trouble to be isolated.

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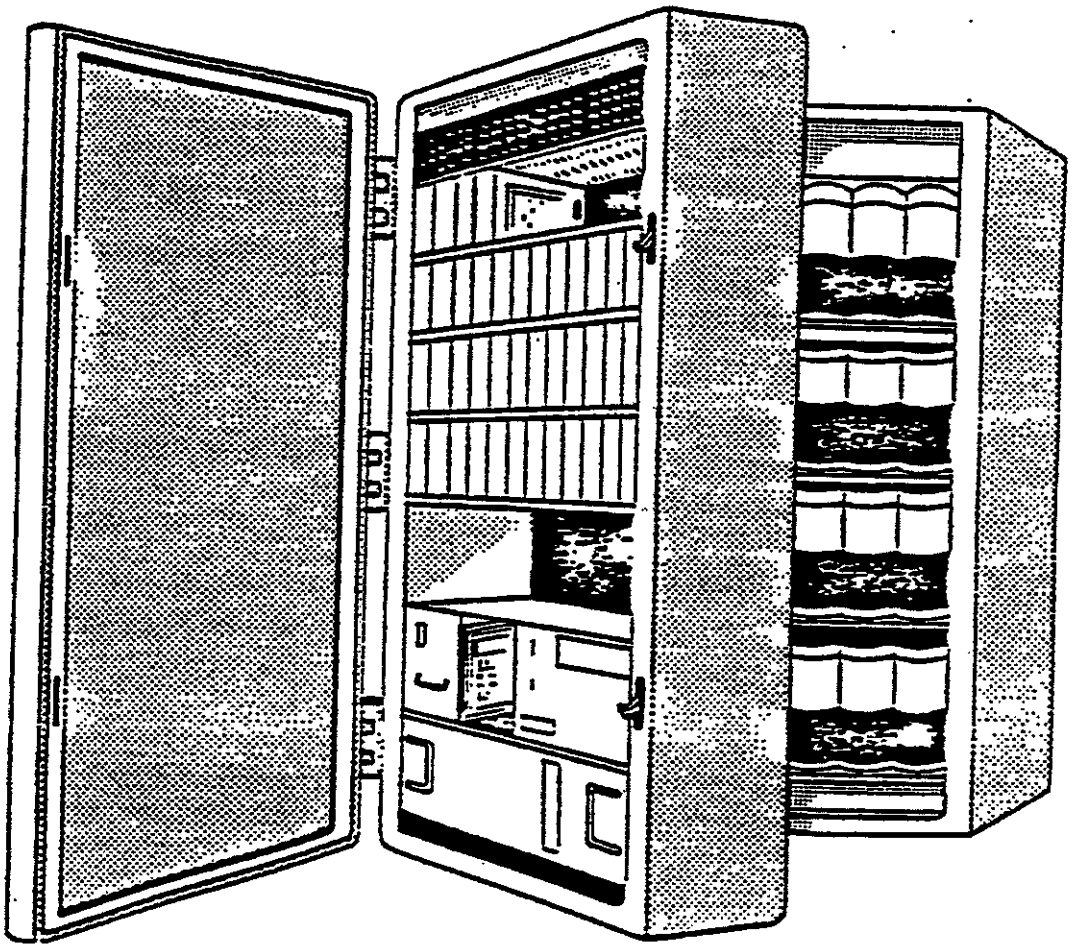
Terminal Cabinet



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SLC-96 - ENCLOSURES

Remote Terminals

Now let's look at several examples of ways Remote Terminals are installed in the field. Enclosures containing SLC-96 terminals include terminal cabinets, mini-huts, Electronic Equipment Enclosures, or Controlled Environment Vaults.

RT Cabinets

Remote Terminal cabinets consist of a weatherproof housing, a front door, and compartmentalized electronics and battery sections.

The terminal cabinet can be pedestal-mounted on a concrete pad, mounted on poles with metal crossarms, or mounted on a pole.

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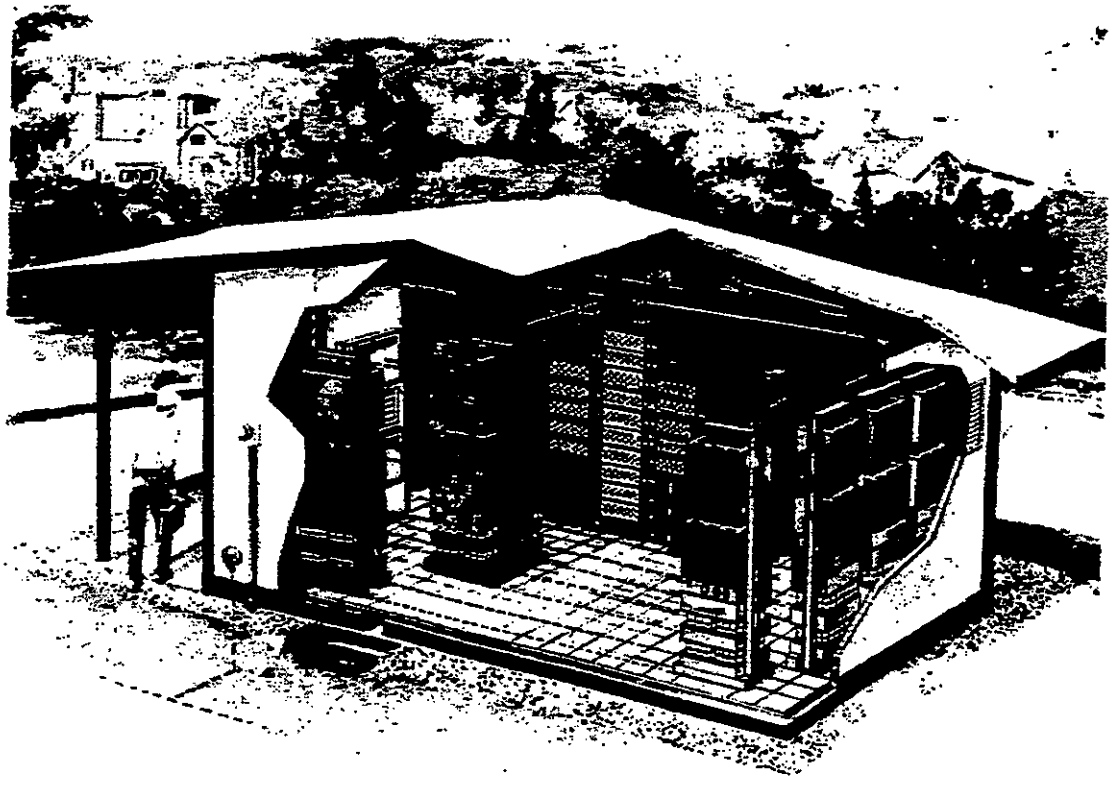
Mini-hut



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SLC-96 - ENCLOSURES, continued

Mini-huts

Mini-huts are designed for up to 10 SLC-96 systems. They are small, walk-in buildings, 6 by 10 feet with an 8 foot ceiling. The outside plant cables are brought in through conduit in the floor.

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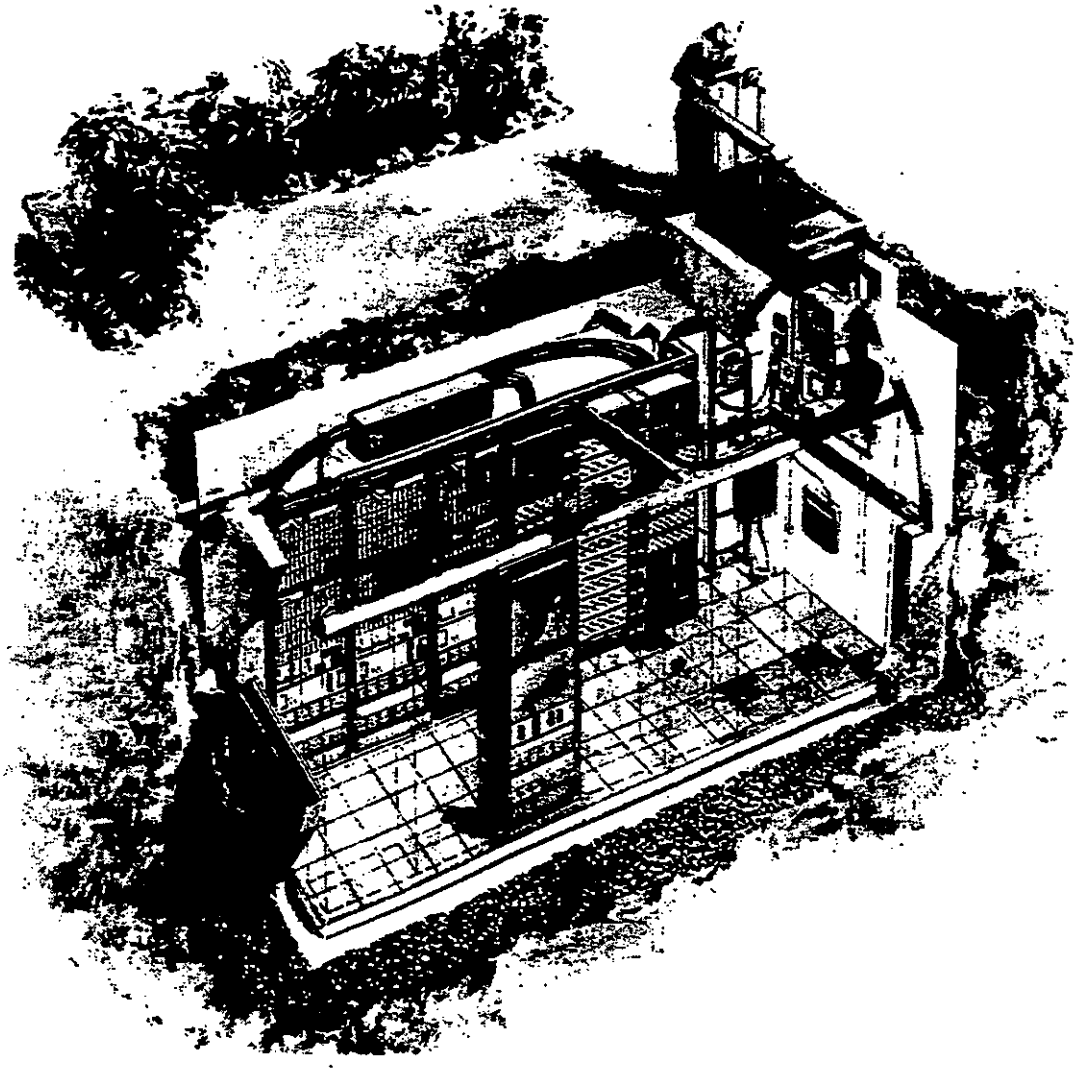
Controlled Environment Vault



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SLC-96 - ENCLOSURES, continued

Controlled Environment Vault

A Controlled Environment Vault is designed to be buried underground. It will house 20 systems. It is 6 feet wide by 16 feet long and 9 feet high. It consists of two precast concrete boxes, a top and bottom half. At the site, the two halves are joined and sealed to make a watertight room. The vault is accessible through a hatchway.

Construction

At the factory, the supplier installs in the top half most of the basic and environmental-control equipment (i.e., lighting, power outlets, cable ports, ventilation system, air conditioner, gas monitor, and visual-audible air quality alarm panel). At the site, the bottom section is placed in a previously-dug and leveled hole, about 12 feet deep.

A platform containing the SLC-96 equipment is installed and the top half secured; the unit is then covered with two feet of earth.

The design of the finished structure allows control of the air temperature and humidity within the vault. Humidity, temperature, air quality, water intrusion and unauthorized entry are continually monitored by alarms.

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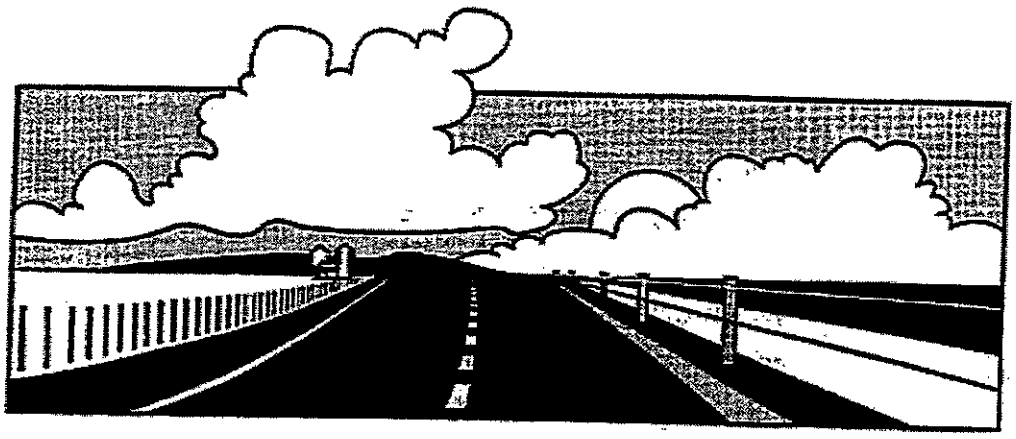

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REVIEW

1) As with D-type Channel banks, a SLC-96 bank contains both Common Units and Channel Units.

2) List at least one maintenance feature of the SLC-96.
Switch to post backup line, monitoring features

3) Identify the following enclosures.
   a) Weather-proof housing with a front door; may be mounted on concrete pads or on poles. Terminal cabinet
   b) Small, walk-in buildings approximately 6'X10'. remote huts
   c) Buried concrete "boxes," accessed through a hatch, with air and temperature monitoring. buried vaults

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REVIEW - ANSWERS

1) As with D-type Channel banks, a SLC-96 bank contains both **Common Equipment** Units and **Channel** Units.

2) List at least one maintenance feature of the SLC-96.
Any of the following are acceptable answers.
   - **Continuous monitoring of performance characteristics of channel groups.**
   - **Alarm displays at the Central Office Terminal and Remote Terminal show system status and aid in corrective maintenance.**
   - **Transmission of alarms to a remote alarm maintenance center.**
   - **Automatic switching to a protection line.**
   - **Remotely controlled test of the customer channel and loop beyond the Remote Terminal.**
   - **Sectional fault locating can isolate digital line troubles.**

3) Identify the following enclosures.
   a) Weather-proof housing with a front door; may be mounted on concrete pads or on poles. **Terminal Cabinet**
   b) Small, walk-in buildings measuring approximatelsy 6'X10'. **Mini-hut**
   c) Buried concrete "boxes," accessed through a hatch, with air and temperature monitoring. **Controlled Environment Vault**

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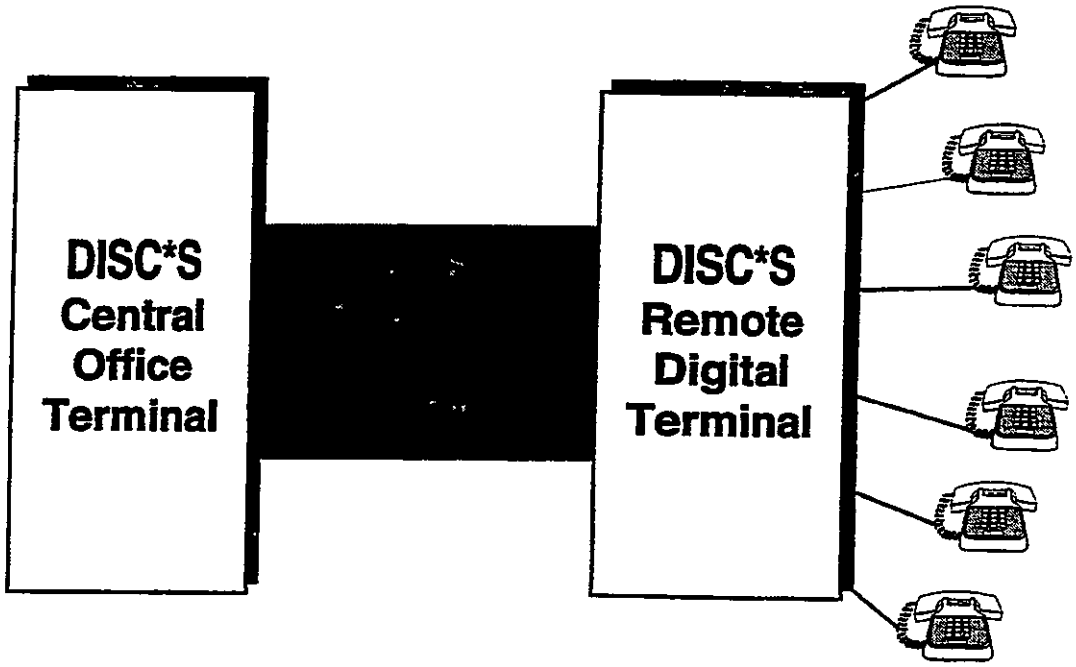
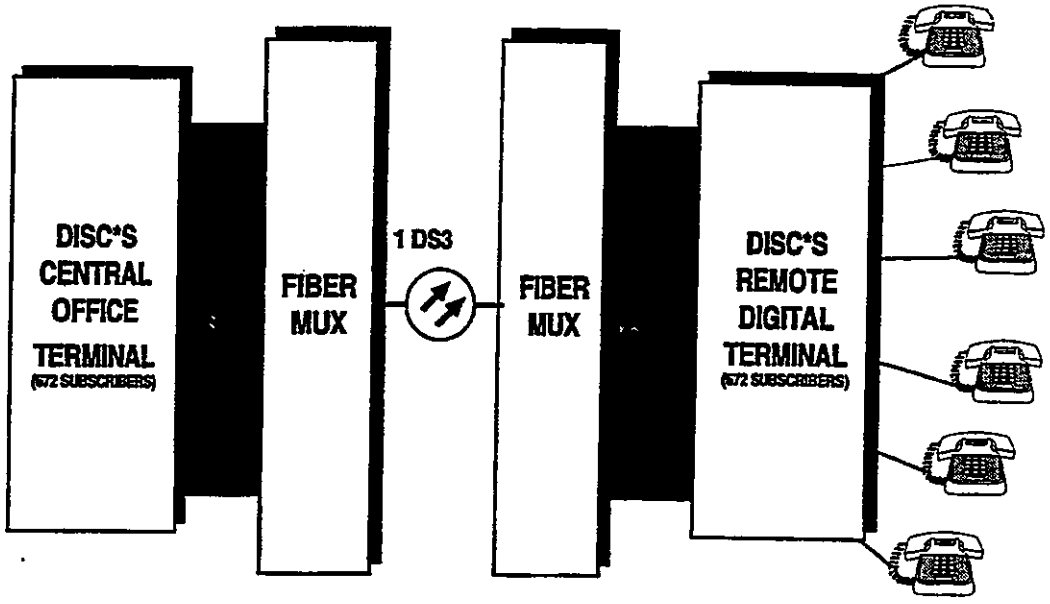
DISC*S System





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DIGITAL INTELLIGENT SUBSCRIBER CARRIER SYSTEM - DISC*S

Our second example of a Digital Loop Carrier system is the Digital Intelligent Subscriber Carrier System, referred to as DISC*S, manufactured by Reliance Comm/Tec.

Capacity

Fully equipped, the DISC*S terminal will support up to 672 subscribers over 28 DS1 lines, each operating at a standard 1.544 Mbps rate.

Examples

As shown in the top illustration, transmission can take place over copper cable pairs, fiber optic cable, or radio facilities (microwave).

Further multiplexing enables transmission at the DS3 rate, over fiber facilities, as shown in the lower illustration.

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DISC*S Components

System components of DISC*S include:

- The Central Office Terminal
- The Remote Digital Terminal
- The Supervisory System

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DISC*S - COMPONENTS

Components

The system components of DISC*S include:

- The Central Office Terminal
- The Remote Digital Terminal
- The Supervisory System

The Central Office Terminal provides the multiplexing/demultiplexing functions, the interface to the network, software control and alarm information.

Capabilities

Each Central Office Terminal can support up to 16 Remote Digital Terminals.

The Remote Digital Terminal provides the same functions as the Central Office Terminal, only at a remote location.

The Supervisory System is a computer, providing the base for data as it applies to the operation and alarm reporting capabilities of the DISC*S system.

Let's look at each of these components a little closer.

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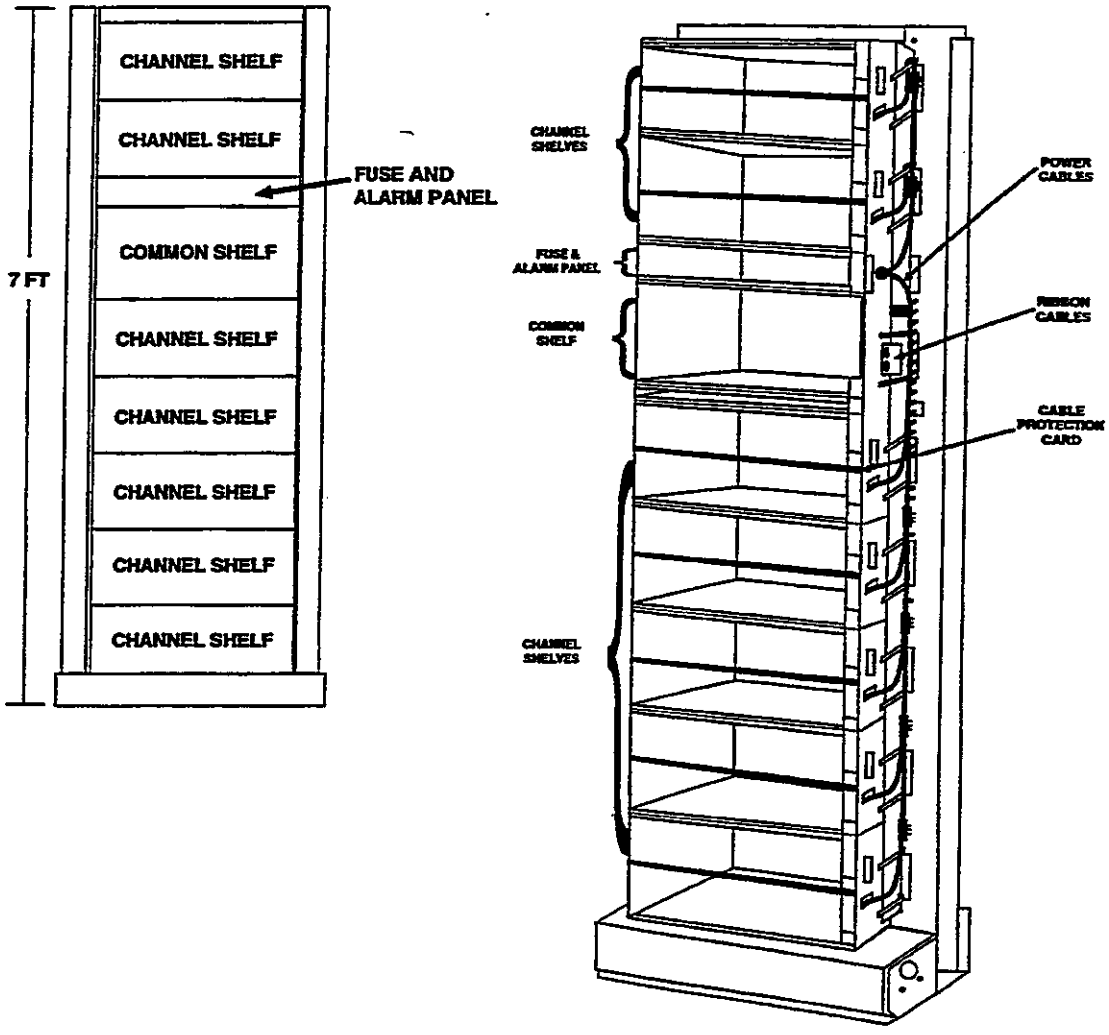
Equipment Rack



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DISC*S - COMPONENTS, continued

Central Office Terminal	The Central Office Terminal is physically located in the Central Office.
Equipment	The equipment, mounted in an equipment rack, consists of 1 Common Shelf, up to 7 Channel Shelves, and a fuse and alarm panel, as shown in the illustration.

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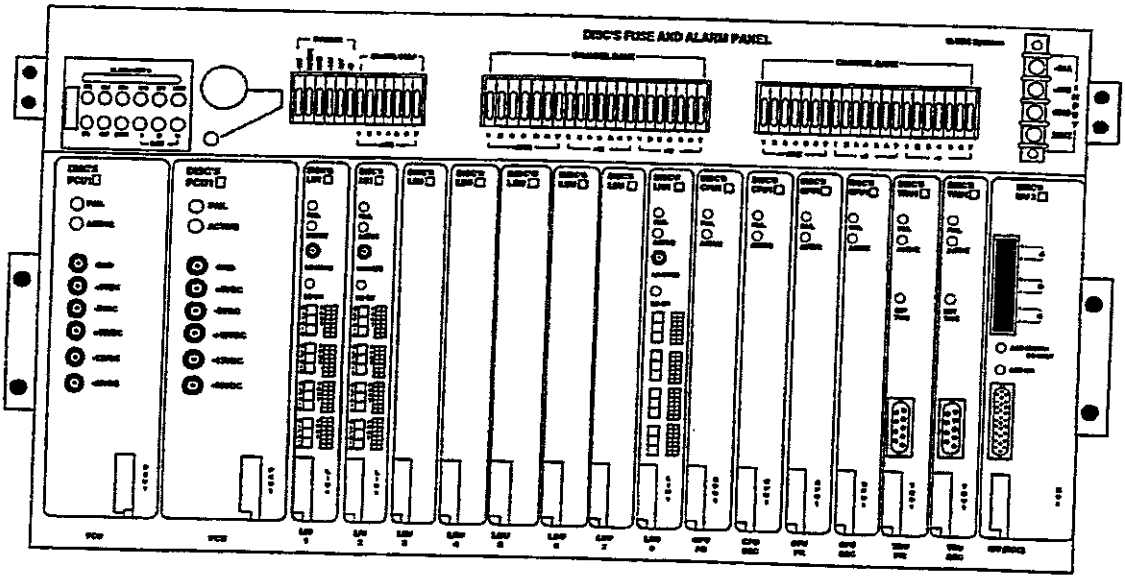
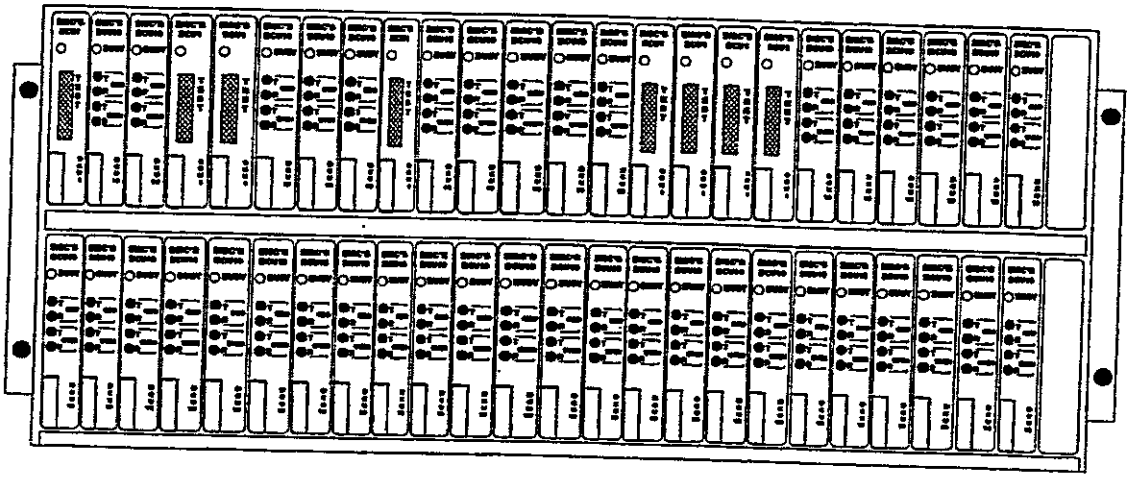
Fuse and Alarm Panel



Common Shelf

Channel Shelves



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DISC*S - COMPONENTS, continued

Fuse and Alarm Panel	The Fuse and Alarm Panel provides protection for all voltages associated with the system.
Common Shelf	The Common Shelf provides all the power for the system, interface to the copper or fiber network, software control for the major functions, alarm information, and communications interfaces.
Channel Shelves	Each Channel Shelf houses up to 96 subscriber lines. Each Channel Shelf can house up to 48 Channel Units, which provide a variety of service options (e.g., Plain Old Telephone Service or POTS, Coin, PBX, WATS, Foreign Exchange Lines, etc.)

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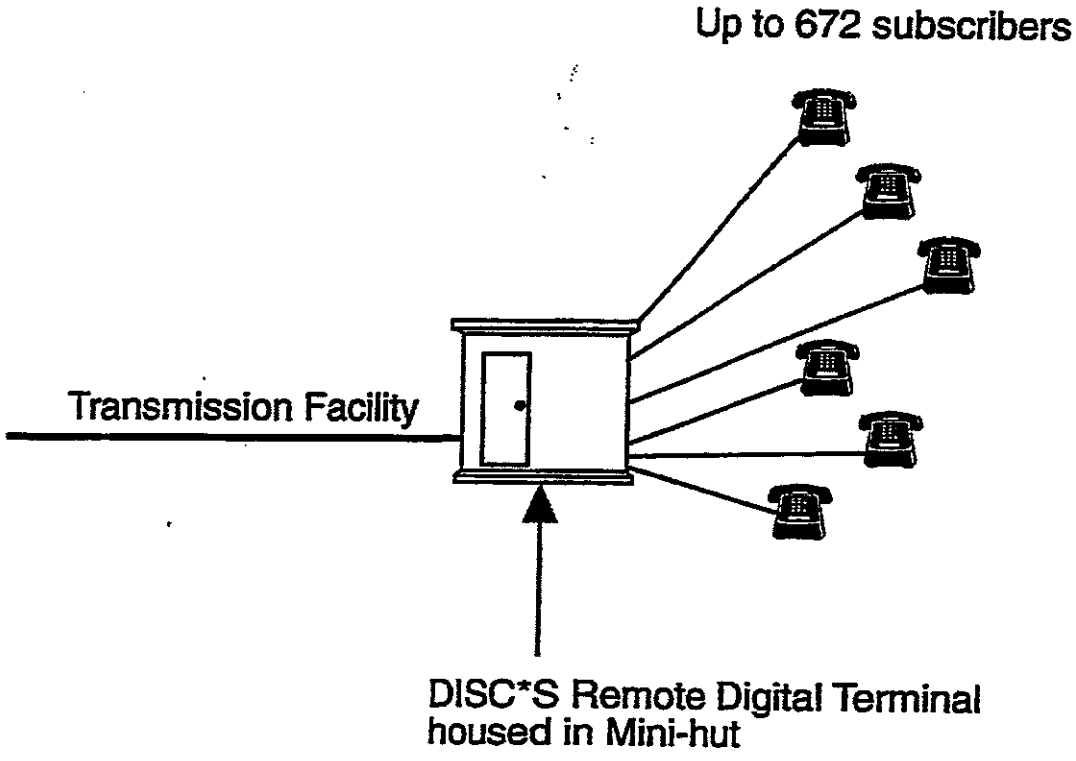
DISC*S Remote Digital Terminal



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DISC*S - REMOTE DIGITAL TERMINAL

Remote Digital Terminal

The Remote Digital Terminal is available in different configurations: in a cabinet, a hut, a Controlled Environment Vault, or in an equipment room.

The equipment is the same as the Central Office Terminal: 7 Channel Shelves, 1 Common Shelf, and a fuse and alarm panel.

Each Channel Shelf supports up to 96 subscribers. The Remote Digital Terminal can support up to 672 subscribers.

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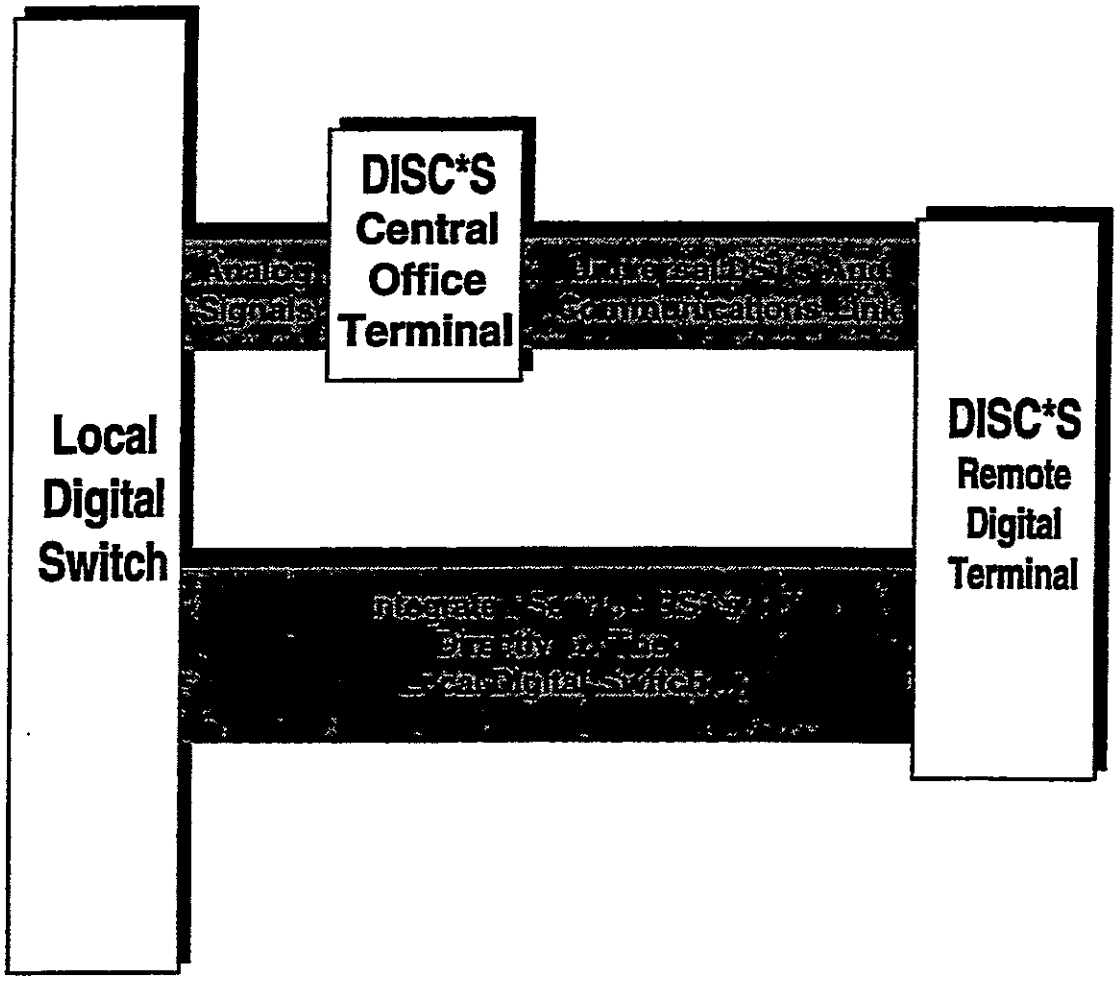
DISC*S Universal, Integrated Arrangements



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DISC*S - INTEGRATED/UNIVERSAL

Integrated, Universal

The DISC*S system is available in an integrated or "universal" arrangement, or both, as illustrated by the diagram.

Integrated

The integrated mode allows the DS1s to be linked directly to the local digital switch. The digital switch must meet technical interface specifications and requirements. Alarm conditions are reported through the local digital switch. Detailed alarm information is available through the Supervisory System.

Universal

The universal mode uses a Central Office Terminal and a Remote Digital Terminal for the DS1 links. Each Channel Unit at the Remote Digital Terminal will have an associated Channel Unit at the Central Office Terminal to provide customer service.

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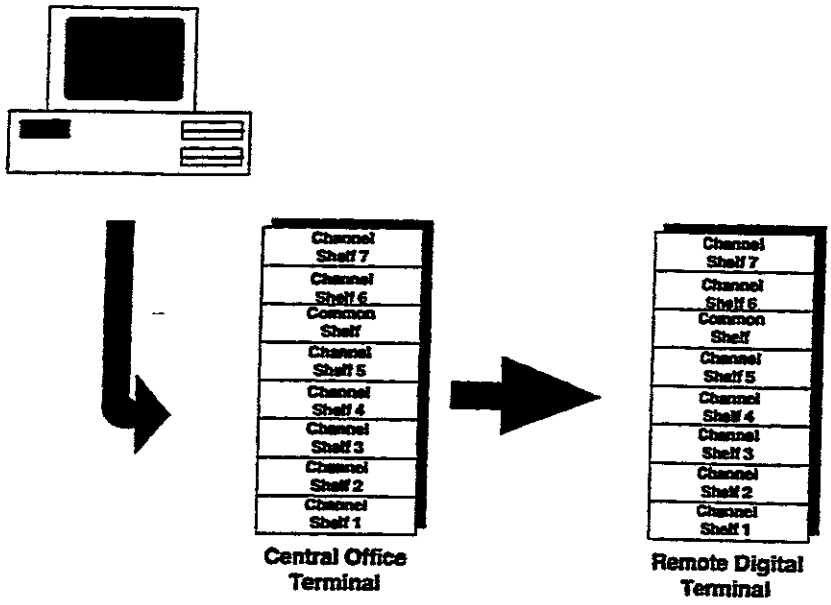
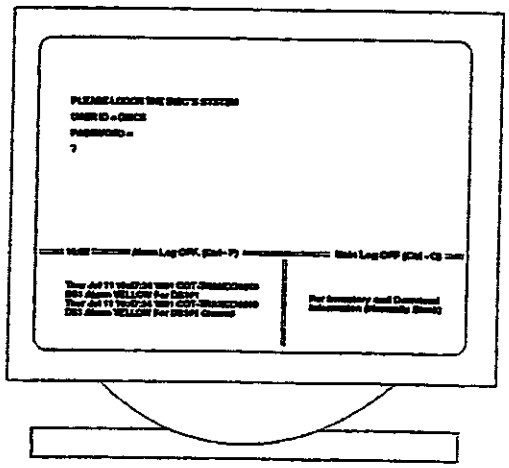
DISC*S Supervisory System





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DISC*S - SUPERVISORY SYSTEM

Supervisory System

The DISC*S Supervisory System is a computer system that allows access to the system to perform initialization, configuration, performance monitoring and diagnostics. It also provides detailed alarm information.

The Supervisory System provides access to the carrier system with command entry, either from the Supervisory System computer, or from remote locations using dial-up facilities.

The Supervisory System offers channel and system diagnostics capabilities to aid in identification of defective equipment. Channel diagnostics may be performed on a routine or demand basis, in response to alarm conditions.

Using the diagnostic capabilities, location and probable fault can be determined before dispatch is made.

The Supervisory System stores alarm information for a seven day period, which may aid in identifying recurring failures.

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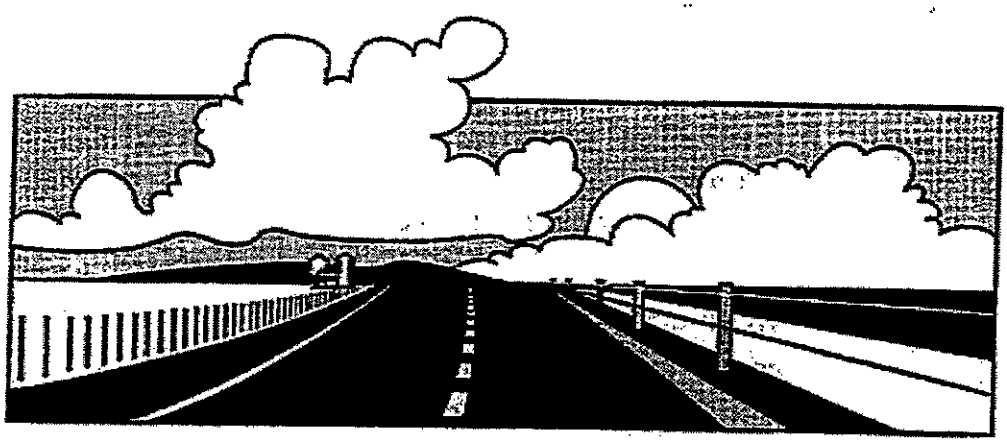

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REVIEW

1) Each DISC*S Central Office Terminal can support up to 16 Remote Digital Terminals.

2) Identify the following DISC*S shelves.
This shelf provide all of the power for the system, the copper or fiber network interface, software control, alarm information and communications interfaces. Common Shelf

This shelf houses up to 96 subscriber lines and provides a number of service options, such as POTS, coin, and PBX.
Channel Shelves

3) DISC*S is available in two arrangements, or modes. The Integrated mode allows the DS1s to be linked directly to the local digital switch. The Universal mode uses a Central Office Terminal and a Remote Digital Terminal for the DS1 links.

4) List at least one function of the DISC*S Supervisory System.
Diagnostics

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REVIEW - ANSWERS

1) Each DISC*S Central Office Terminal can support up to **16** Remote Digital Terminals.

2) Identify the following DISC*S shelves.
This shelf provide all of the power for the system, the copper or fiber network interface, software control, alarm information and communications interfaces. **Common Shelf**

This shelf houses up to 96 subscriber lines and provides a number of service options, such as POTS, coin, and PBX. **Channel Shelf**

3) DISC*S is available in two arrangements, or modes. The **integrated** mode allows the DS1s to be linked directly to the local digital switch. The **universal** mode uses a Central Office Terminal and a Remote Digital Terminal for the DS1 links.

4) List at least one function of the DISC*S Supervisory System. Any one of the following answers is acceptable: **initialization, configuration, performance monitoring, diagnostics, and alarm information.**

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DMS-1 Urban:

- Digital Loop Carrier system
- Accommodates up to 544 subscriber lines
- Uses DS1 transmission lines
- Can utilize copper cable pairs, digital radio, or fiber optics
- Examples of applications include industrial parks and residential subdivisions

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DMS-1 URBAN

Overview

The last Digital Loop Carrier example we'll study is the DMS-1 (Digital Multiplex System-1) Urban, by Northern Telecom. The DMS-1 system provides telecommunications service from a Wire Center to residential and business customers in the local loop.

As with the other examples we looked at, the SLC-96 and the DISC*S, the purpose of the DMS-1 Urban is to generate, transmit, and receive a digital signal between two terminals, taking many subscribers and combining their transmissions so that the signals can be sent to the distant end via a few cable pairs.

System Size

The DMS-1 Urban system accommodates up to 544 lines, in various mixes of Plain Old Telephone Service, coin and special services lines. The system uses DS1 transmission lines, utilizing copper cable pairs, digital radio, or fiber optic cable.

Application

The main application of the DMS-1 Urban is to increase the number of subscribers that can be economically served by cable pairs between the Central Office and the remote location. Typical applications include industrial parks, apartment complexes, shopping centers, and residential subdivisions.

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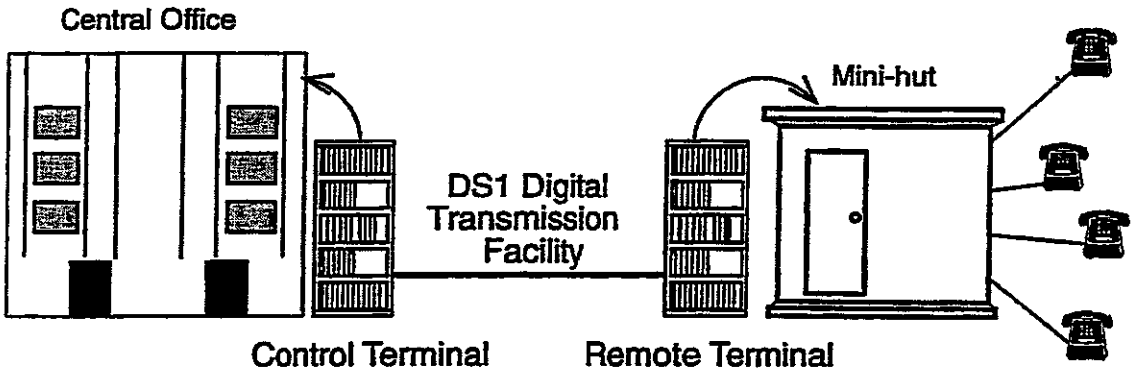
DMS-1 Urban



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DMS-1 URBAN - COMPONENTS

Components

The DMS-1 Urban consists of the following components:

Control Terminal

A Control Terminal, installed in the Central Office, which provides.

- The analog - digital interface for lines such as POTS, Coin, and Special Servies
- Multiplexing of subscriber signals for transmission on digital lines

Remote Terminal

A Remote Terminal, located at a remote location from the Central Office and located near the customers served by the system. It provides:

- The analog - digital interface for lines such as POTS, Coin, and Special Services
- Multiplexing of subscriber signals for transmission on digital lines

Communications Links

Communication Links at the DS1 signal level, as follows:

- Fiber optic or copper cable pairs to carry subscriber signals and system control signals between the Control Terminal and the Remote Terminal. For transmission over fiber, a Digital Fiber Interface multiplexes DS1 signals and converts the electrical signals into optical signals.

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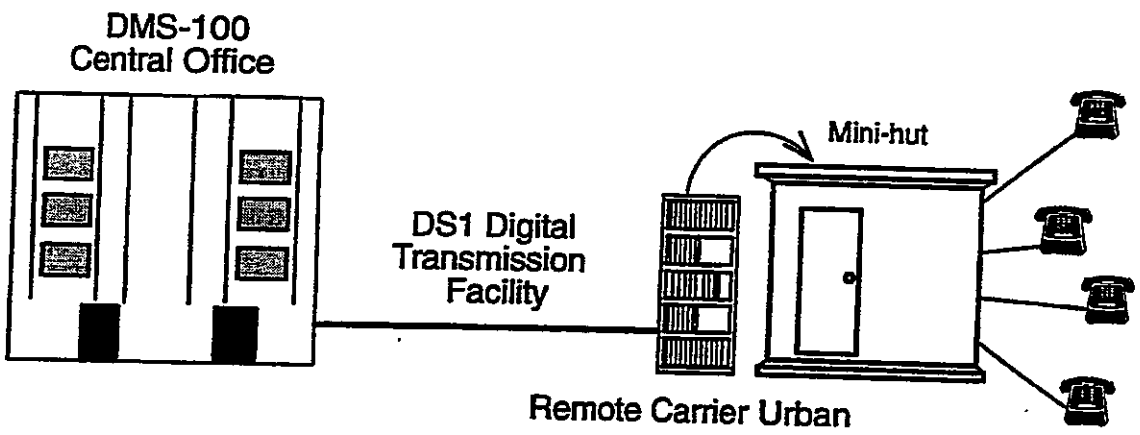
Integrated DMS-1 Urban



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INTEGRATED DMS-1 URBAN

Integrated DMS-1

When a DMS-1 Urban interfaces with a DMS-100 digital switch, a Control Terminal is not required. The Control Terminal is replaced by a peripheral module called the Subscriber Carrier Module - 100U.

The Subscriber Carrier Module allows a DMS-100 switch to interconnect with the remote unit on a direct digital basis. This remote unit, very similar to the Remote Terminal, is called a Remote Carrier Urban, or RCU.

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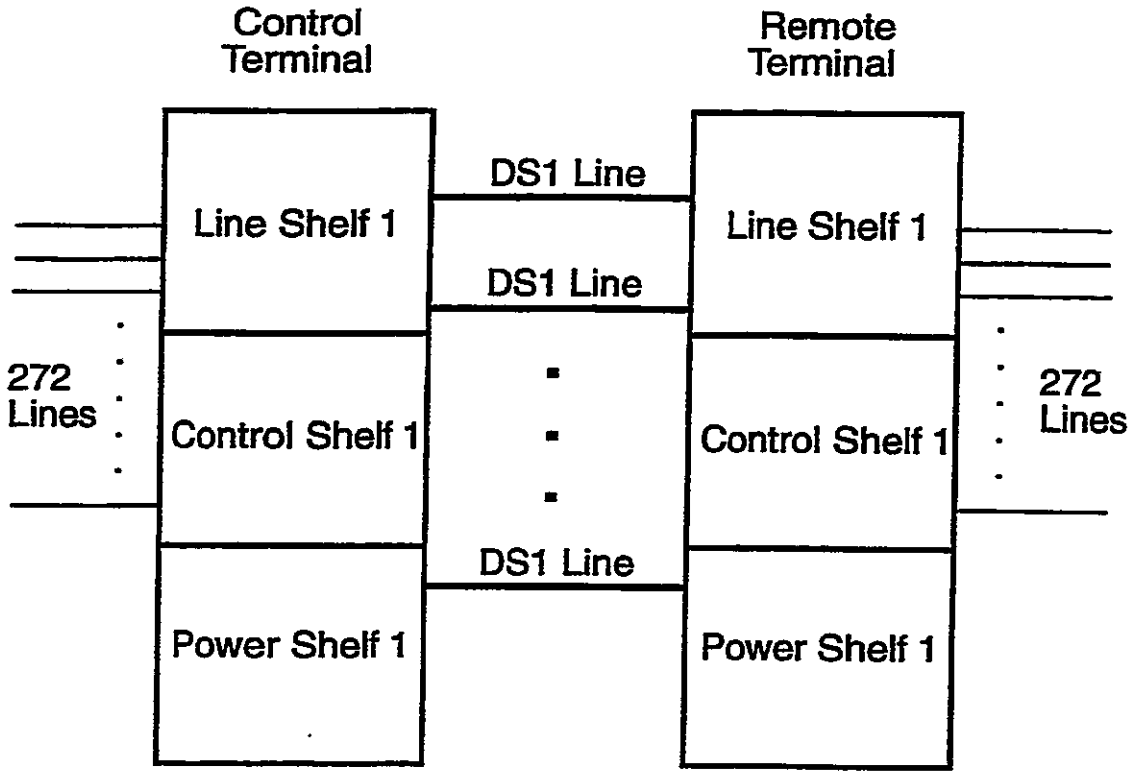
DMS-1 Urban One-Group System



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DMS-1 URBAN - SYSTEMS

Let's look at a couple of examples of DMS-1 systems.

One-Group System

We'll start with a One-Group System. Shown on the opposite page, a single line-group system consists of 3 equipped shelves - Power Shelf 1, Control Shelf 1, and Line Shelf 1.

Line capacity of this system is 272, without the Special Services Module (SSM) installed. (The SSM accommodates a wide range of special services, including data.)

Other features of the one-group system include:

- ⇛ Duplicated common equipment
- ⇛ System maintenance features
- ⇛ Multiple digroups share the traffic load; if the transmission quality of one digroup deteriorates, traffic is distributed among the other digroups.
- ⇛ One office repeater per digroup

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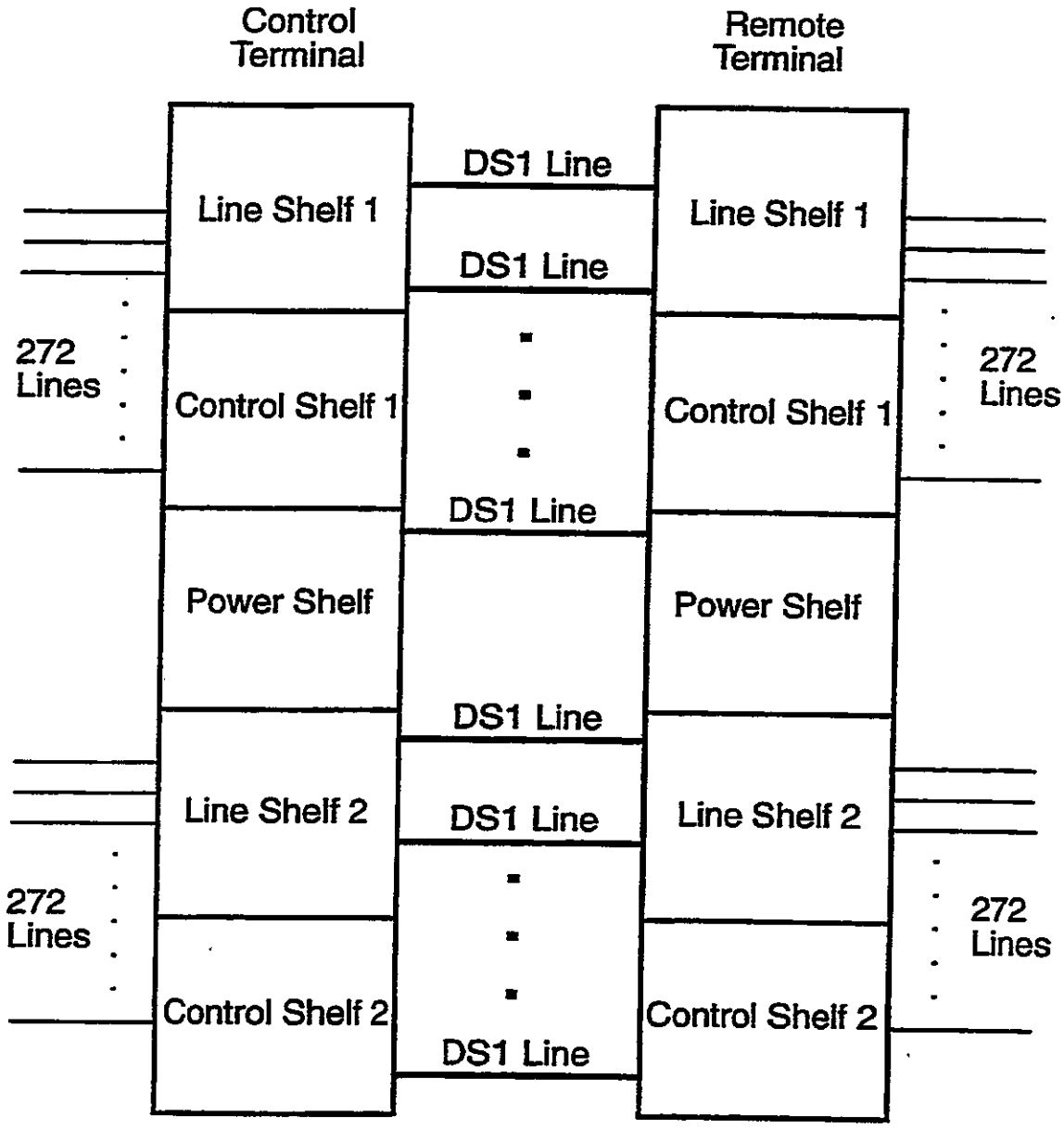
DMS-1 Urban Full System



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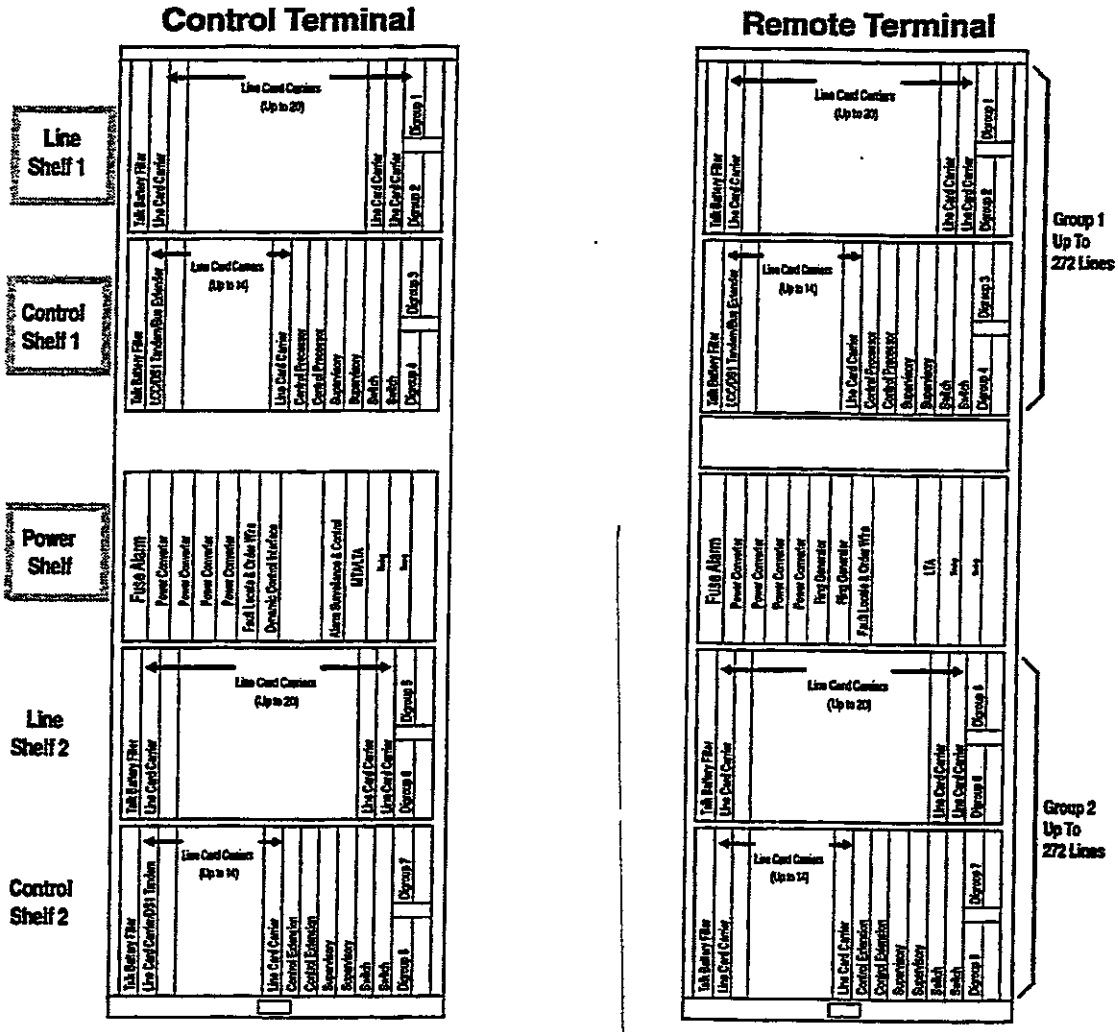
DMS-1 URBAN - SYSTEMS, continued

Full System

The figure on the opposite page illustrates a full system. It can consist of 5 system shelves. The 5 system shelves can provide space for 544 lines.

DMS-1 Urban - Line, Control & Power Shelves



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DMS-1 URBAN - PHYSICAL SHELVES

Physical Shelves

Let's look briefly at the functions of the physical shelves that make up the Control Terminal and the Remote Terminal. These are the Line Shelf, the Control Shelf, and the Power Shelf.

Line Shelf

The Line Shelf houses equipment that provides a point of access for subscriber lines to enter the DMS-1 equipment. The equipment provides the analog to digital conversion, and DS1 signal monitoring.

Control Shelf

The Control Shelf houses equipment that performs the multiplexing functions, and line status scanning.

Power Shelf

The Power Shelf's functions include power distribution and conversion for the system, ringing signal generation, line test access for testing subscriber loops at the Remote Terminal, and alarm and equipment indicators.

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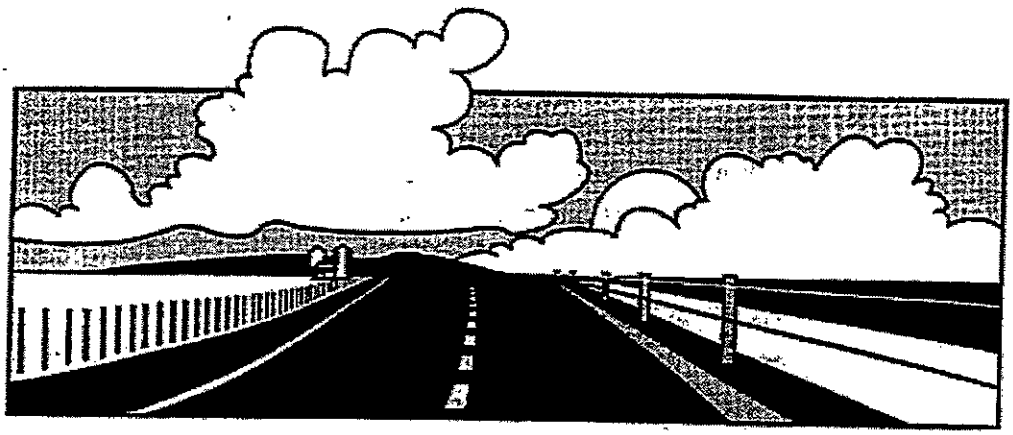

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REVIEW

1) The DMS-1 Urban full system accommodates up to _____ lines.
• 672 • 544 • 496 • 522

2) List the three main components of the DMS-1 Urban.
~~Line, Control, Panel~~ Control
Remote
Comm Link

3) In an integrated DMS-1, a Control Terminal is not required.

4) Name the three equipment shelves of the DMS-1 Urban.
Line
control
Panel

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REVIEW - ANSWERS

1) The DMS-1 Urban full system accommodates up to **544** lines.

2) List the three main components of the DMS-1 Urban.
Control Terminal
Remote Terminal
Communications Links

3) In an integrated DMS-1, a **Control** Terminal is not required.

4) Name the three equipment shelves of the DMS-1 Urban.
Line Shelf
Control Shelf
Power Shelf

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UNIVERSAL DIGITAL CHANNEL (UDC)

☞ **A Miniplex system consists of line cards housed in universal shelves with heat deflectors mounted in a Central Office standard configuration 7ft. by 23in. wide frame, linked to a line – powered Remote Terminal (RT).**

- ✓ **Provides up to four lines of single-party message service over a single copper pair**
- ✓ **System consists of a line card within a Central office bay shelf linked to a Remote Terminal (RT)**
- ✓ **Provides one Voice Frequency (VF) POTS service line and one basic rate ISDN line over a single copper pair.**

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UNIVERSAL DIGITAL CHANNEL – INTRODUCTION

Introduction

The Universal Digital Channel (UDC), manufactured by Raychem Corporation, is a Digital Subscriber Line (DSL) multiplexing system, providing up to four VF circuits, each utilizing a 64 kbps channel over a single non-loaded copper pair.

Also referred to as a Miniplex, the UDC systems consist of a Central Office preconfigured bay, complete with 10 universal shelves, heat deflectors and an associated Remote Terminal, located at a subscriber's site.

A line card installed in a universal shelf at the CO coupled with a Remote Terminal, makes up a line set, providing either two or four POTS- type derived subscriber lines over a single copper wire.

The Miniplex VF+ISDN version system offers one VF POTS service line and one Integrated Services Digital Network (ISDN) line on a single copper pair.

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UDC Benefits

- ✓ Rapidly deployed
- ✓ Copper relief
- ✓ Cost savings
- ✓ Simultaneous voice and data capability
- ✓ Getting the most from existing copper facilities

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UDC – FACTORS AND BENEFITS

Benefits	There are a number of benefits to UDC. Various System configurations can be rapidly deployed, making it possible to provide additional telephone numbers, including ISDN service over a single copper pair.
	It translates into "copper relief" when there is no immediate need to invest additional capital into the copper infrastructure.
	At the same time, additional copper placement is being curtailed as US WEST decides in favor of fiber, fiber / coax or wireless services for future broadband delivery capability.

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UDC SYSTEM CONCEPTS

- **Cost effective way to increase the capacity of copper networks**
- **Integrated voice and data on the same line**
- **The answer to home offices needing a data line with a second and third phone line.**
- **End to end digital connectivity**
- **Satisfies internet demand for new access lines**
- **ISDN services**
- **Fully line powered from the CO to the Remote Terminal**

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UDC – CONCEPTS AND PARAMETERS

How it works

Miniplex UDC-2; 2N1 UDC Product.	Provides two independent VF lines at 64 kbps rate per channel over a non-loaded single copper pair.
Miniplex UDC-4; 4N1 UDC Product.	Provides four independent VF lines at 64 kbps rate per channel over a non loaded single copper pair.
MinipleMx UDC-24; 24 channel System.	An integration of six Miniplex UDC-4 systems composed of a total of 24 VF lines over six existing non-loaded cable pairs.
Miniplex VF+ISDN System.	Provides one VF line and one Basic Rate ISDN line over a non-loaded cable pair.
Remote Terminal (RT) at Subscriber's Site	Multiplexes and demultiplexes DSL signals, converted to analog and back, at the subscriber lines. The RT is DSL powered. No battery or local power is required.
Subscriber Network Interface Device (NID)	At the subscriber's location, The NID normally provides station protection and wire terminals. When required, the NID itself can be re-configured with a replacement door, that will contain an electronics package to be the equivalent of a Remote Terminal.

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CONCLUSION

This concludes Module 1, Book II. Before taking the test, you may review the material in the module. There is an index of subjects for Book II on the following pages. Clear up any questions you may have with the instructor. Return to the beginning of Book II and review the objective. When you are ready, ask your instructor for a copy of the test for Module 1, Book II.

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SUBJECT INDEX - BOOK II

Subject	Page
AT&T DACS	73
DCS	
Access and testing	55
Comparison with DSX	33
Components	65
Description, overview	31
Input/output commands	67
System	63
Test Configuration	57
DCS Reconfiguration	
Channel Bank replacement	49
Concentration	39
Segregation/grooming	45
DEX CS1 DCS	75
Digital Loop Carrier	
Advantages	91
Vendors	97
DISC*S	
Capacity/transmission	127
Capabilities	129
Central Office Terminal	131
Common, channel shelves	133
Components	129
Integrated/Universal	137
Remote Digital Terminal	135
Supervisory system	139

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SUBJECT INDEX - BOOK II, continued

Subject	Page
Distributing frame	
Connections	11
Functions	13
Overview	5
Purpose	11
DMS-1 Urban	
Capacity/transmission	145
Components	147
Control Terminal	147
Full System	153
Integrated DMS-1	149
One-group System	151
Overview	145
Physical shelves	155
Remote Terminal	147
DSX	
Bays	21
Bay types, panels	23
Jacks	23
Looping, patching	25
Overview, purpose	19
System route	21
EDSX	169
Fiber Distribution Panel	81
Connections	83
LEN	11
Loop electronics	89
Pair Gain Systems	89

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SUBJECT INDEX - BOOK II, continued

Subject	Page
SLC-96	
Central Office Terminal/Remote Terminal	113
Channel Bank/T1 lines	105
Controlled Environment Vault	121
Integrated system	103
Maintenance Features	115
Mini-hut	119
Operation	105
Overview	99
Remote Terminal	117
System	41
Types of special service circuits	43
Tellabs 532 TCS	77
UDC	
Purpose and preview	160
Introduction	162
Benefits	164
Components	166

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Introduction to Digital Technologies for COT

US*WEST*
COMMUNICATIONS

Module 1, Book III
Understanding Digital Concepts And Components

January, 2000

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0.01	Revised original course material and updated test questions	01/11/00	M1 B3 intro.doc M1 B3 ptE.doc M1 B3 ptF.doc

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INTRODUCTION

Overview

Module 1, Book III of *Understanding Digital Concepts and Components* is comprised of the following parts:

Part E: Fiber Optics

Part F: ISDN

After completing Book III, you will take a test before going on to the next module. We will only test on material in Book III; no material from Book I or II will be included.

Each Part will list its purpose and the subjects to be covered.

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OBJECTIVE - BOOK III

Objectives

At the conclusion of Parts E and F of this module (Book III), the student will be able to correctly:

- ✔ Identify the terms, concepts, properties and components of fiber optics.
- ✔ Identify the concepts, terms, interfaces, and applications of ISDN.

The student will be provided with a written test, comprised of multiple choice and matching term to definition type questions. During the test, the student may not refer to any reference material.

Evidence of satisfactory learning will be demonstrated by correctly completing 26 out of 32 questions on the test.

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Table of Contents

PART E: FIBER OPTICS 1
PURPOSE AND PREVIEW 1
Purpose 1
Preview 1
FIBER OPTICS - INTRODUCTION 3
Introduction 3
ICE Age 3
Overview 3
Symbol 3
Applications 3
ADVANTAGES OF FIBER 5
Advantages 5
Low Attenuation 5
Large Bandwidth 5
Ease of Handling 5
Resistance to Interference 5
Improved Security 5
REVIEW 7
FIBER OPTICS - HISTORY 11
Bell's Photophone 11
MAJOR FIBER OPTIC MILESTONES 13
1950s 13
1960 13
1966 13
1970 13
Early 70s 13
1976 13
1983 13
PROPERTIES OF LIGHT 15
Light Ray 15
Speed 15
Propagation 17
Wavelength/ Frequency 17
REVIEW 19
Spectrum 23

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REFRACTION OF LIGHT 25
Refractive Index 25
Example 27
REVIEW 29
TERMS 33
Incident Ray 33
Angle of Incidence 33
Law of Reflection 33
Refracted Ray 33
Reflected Ray 33
Critical Angle 35
Total internal Reflection 37
Verification of Principle 37
Numerical Aperture 39
Acceptance Cone 39
Cladding 39
REVIEW 41
OPTICAL FIBER'S PHYSICAL MAKE-UP 45
Core 45
Cladding 45
Sheath 45
TYPES OF FIBER 47
Multimode 47
Single Mode 47
MULTIMODE STEP INDEX FIBER 49
Description 49
MULTIMODE GRADED INDEX FIBER 51
Description 51
SINGLE MODE STEP INDEX FIBER 53
Description 53
Single Mode Step Index 53
REVIEW 55
DISPERSION 59
Pulse Dispersion 59
Modal Dispersion 59
CHROMATIC DISPERSION 61
Effect 61
Cures 61

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TRANSMISSION LOSS 63
Scattering Loss 63
Splicing Loss 63
FIBER OPTIC CABLE DESIGN 65
Ribbon Design 65
Stranded Design 67
SPLICING 69
Mechanical Splicing 69
Fusion Splicing 69
REVIEW 71
BASIC SYSTEM COMPONENTS 75
Optical System 75
Optical Transmitter 75
Optical Receiver 75
Optical Regenerator 75
LIGHT TRANSMITTERS 77
Transmitter Types 77
Laser 77
LED 77
LIGHT RECEIVERS 79
Functions 79
Factors 79
Detector Types 79
OPTICAL REGENERATORS 81
Function 81
Description 81
Optical Receiver Function 81
Optical Transmitter Function 81
Factors 81
FIBER OPTIC CABLE IN AN OPTICAL SYSTEM 83
Fiber Pairs 83
Protection 83
Regenerators 83
REVIEW 85
FIBER OPTIC EQUIPMENT 89
Major Components 89
C.O. Equipment Functions 89
C.O. Equipment Components 89

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Repeater Station 91
Fiber Distribution Frame 93
General Description 93
Fiber Splice Shelf 93
Fiber Splice Frame 93
DIGITAL HIERARCHY 95
SONET 95
STS and OC Level Signals 95
U S WEST FIBER OPTIC SERVICE 97
General Description 97
Speeds 97
Installation 97
Standard Features 99
Optical Features 99
Applications 99
Examples 99
REVIEW 101
BASIC FIBER APPLICATIONS 105
Dark Fiber 105
Dim Fiber 105
Finished/ Terminated Fiber 105
FIBER LOOP DEVELOPMENTS 107
Formats 107
REVIEW 109

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PART E: FIBER OPTICS

PURPOSE AND PREVIEW

Purpose

The purpose of this section of the module is to enable you to understand the world of fiber optics from a broad perspective; from its theory, to how fiber optic transmission takes place, to the components of the fiber optic system. Fiber optics is the future of telecommunications. We think you'll agree it is important to have a high-fiber diet in your learning!

Preview

Subjects included in this section include:

- ☆ Fiber's advantages
- ☆ History
- ☆ Properties and terms of light
- ☆ Fiber's physical make-up
- ☆ Types of fiber
- ☆ Fiber optic system components
- ☆ Transmitters, receivers and regenerators
- ☆ U S WEST Fiber Optic Service
- ☆ Typical Fiber optics system

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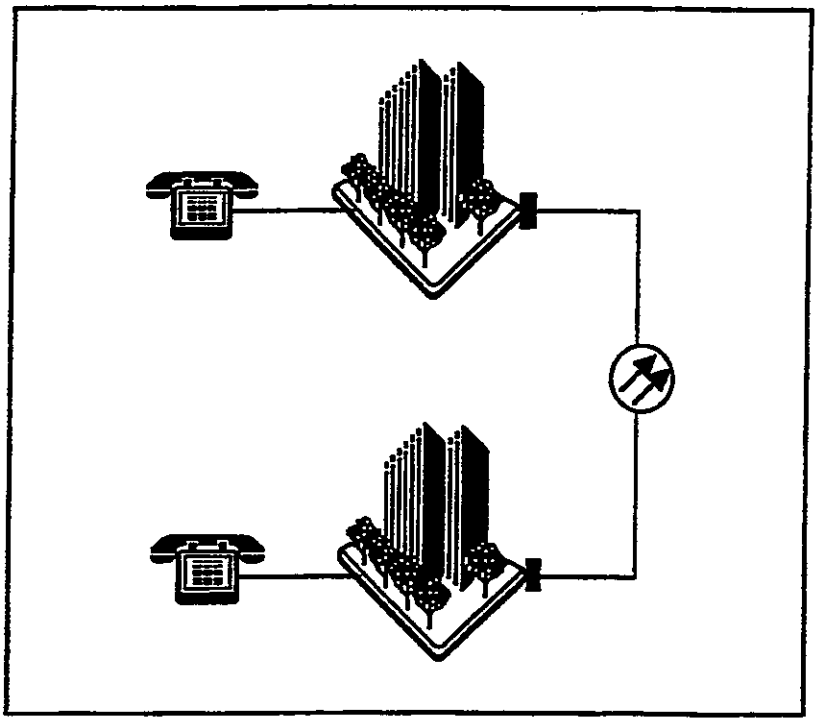
Fiber Optics



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FIBER OPTICS - INTRODUCTION

Introduction

Cross-connect frame systems provide for cross-connection of, and test access to, telephone circuits. Several types of systems have been developed to meet the specific needs of voice frequency, digital carrier and fiber-based systems.

ICE Age

Fiber optics will allow the convergence of three areas - Information, Communications, and Entertainment - the so-called "ICE" age.

Fiber provides a 1,000-fold increase in capacity over copper-based systems. In addition, its wide bandwidth allows transmission of high-quality video, audio and specialized data applications.

Overview

A fiber optic cable is composed of transparent fiber surrounded by a layer of light-bending cladding. The cladding is surrounded by a protective coating. Fiber optic cable is represented in graphics by a unique symbol.

Symbol

Applications

Fiber optic cable is used for medium and large capacity interoffice trunks, long haul intercity routes, and for video, audio, and data hookups. It is being installed in local loop applications.

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Advantages of Fiber

- ✔ Low attenuation
- ✔ Large bandwidth
- ✔ Ease of handling
- ✔ Resistance to electromagnetic interference
- ✔ Improved security

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ADVANTAGES OF FIBER

Advantages

There are numerous advantages to fiber optics. Those that come immediately to mind include its high [illegible] and its virtually [illegible] transmission. It is an excellent transmission medium for [illegible] and other reasons, including:

Low Attenuation

Fiber optic [illegible] material. It provides better long [illegible] transmission than metallic cable, requiring [illegible] repeaters on the span line.

Large Bandwidth

Optical fiber has practically unlimited bandwidth. In fact, a group of researchers asked a computer to estimate the maximum top transmission speed over a single fiber. The computer estimated the ultimate speed to be in the region of 25,000 Gbps. The computer also estimated that at the 25,000 Gbps speed, all the recorded knowledge known to humankind could be transmitted in 20 seconds!

Ease of Handling

Fiber optic cable is relatively small and lightweight. For example, typical fiber-optic cable weighs about [illegible] pounds per thousand feet. It is an ideal choice where excessive weight is a problem. The small physical size of its cables reduce the possibility of blocked underground conduit. In addition, it can also be connected to equipment relatively easily.

Resistance to Interference

Electrical current produces magnetic fields which cause interference. Fiber cables are immune to this interference. Fiber optic cable is an excellent choice in a location where electrical inductance is a problem. In addition, fiber cables are immune to [illegible] and weather interference.

Improved Security

Although tapping into a fiber optic cable is not impossible, it is considerably more difficult than tapping into metallic cable.

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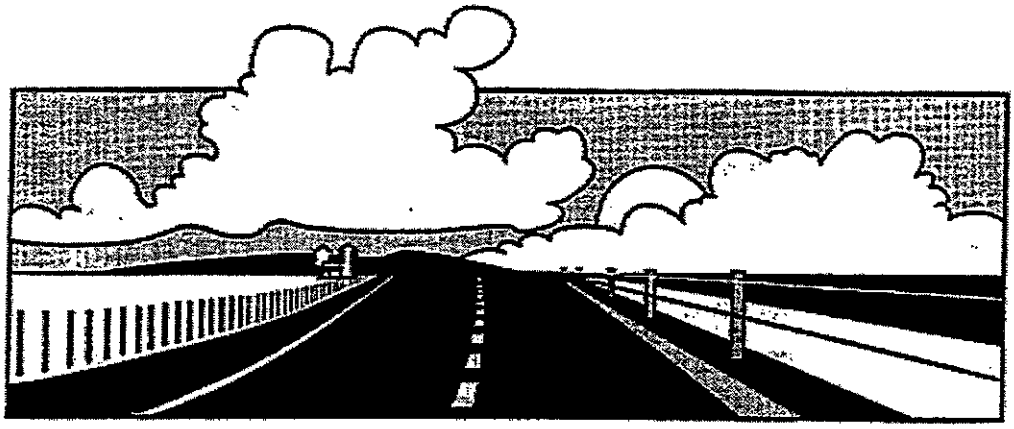

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REVIEW

1) Fiber optic cables are immune to radio, electrical interference.

2) Fiber optic cable requires fewer repeaters on a span line.

3) Fiber optic cable is an ideal choice where excessive inductance, interference is problem.

4) Fiber has practically unlimited bandwidth.

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REVIEW - ANSWERS

1) Fiber optic cables are immune to **electrical** interference.

2) Fiber optic cable requires **fewer** repeaters on a span line.

3) Fiber optic cable is an ideal choice where excessive **weight** is a problem.

4) Fiber has practically **unlimited** bandwidth.

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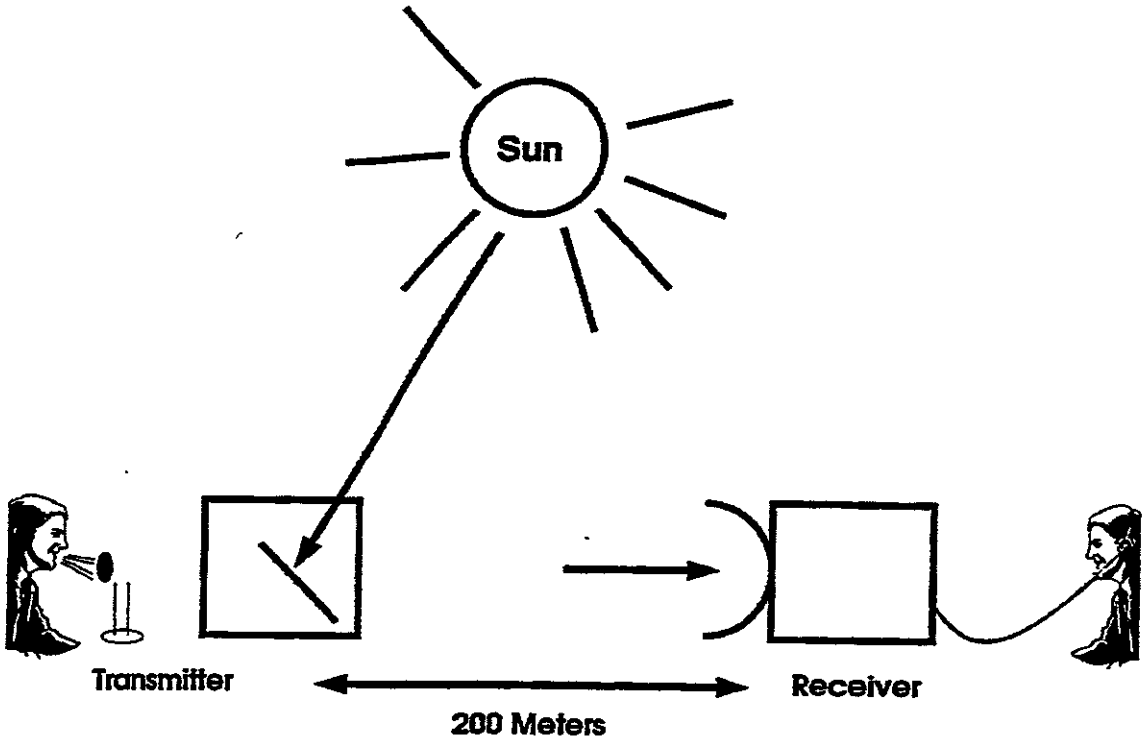
Bell's Photophone



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FIBER OPTICS - HISTORY

Fiber optics or light guide, the idea of sending some light down a glass cable, is a brand new idea, right?

Bell's Photophone

Well, not really. In 1880, our hero, Alexander G.Bell, demonstrated that voice could be transmitted over a modulated beam of sunlight. Although the distance was only 200 meters, and conversations were limited by clouds and sunset, the idea of optical transmission had begun. This invention came only four years after the invention of the telephone, and Bell considered it one of his most notable scientific inventions.

A mirror was used to vibrate according to the speech signal, thereby imposing modulation on the beam of light focused on the receiver. The receiver was a light sensitive selenium unit. As the modulated light was received, the output in the form of electricity was varied, creating an analog voice signal.

Since these experiments used free space as a conductor, they cannot be considered "light guide" tests, but rather radiated light. The idea of containing the light (or guiding it) came later.

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Major Fiber Optic Milestones

1950s - the term, fiber optics, is coined

1960 - first laser demonstrated

1966 - low-loss fibers postulated

1970 - first fibers with < 20 dB/km loss demonstrated

1970 - first practical laser demonstrated

1970s - progressively lower loss glass fiber manufactured

1976 - commercial test of fiber optics

1983 - Single Mode fiber introduced

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MAJOR FIBER OPTIC MILESTONES

1950s In the 1950's, the term, fiber optics, was coined by H. H. Hopkins, and H. S. Kapany of the United Kingdom. These two men invented a flexible fiber scope used to "bend" light.

1960 In 1960, the first laser (Laser - Light Amplification by Stimulated Emission of Radiation) was developed. This provided a powerful method of generating a pure light.

1966 In 1966, K. C. Kao of ITT theorized that a cable made of glass could be drawn, with a loss of less than 1 dB/km. This was a radical idea, since at that time the finest fibers lost 1000 dB/km!

1970 In 1970, Corning Laboratories demonstrated a glass with a loss of only 20 dB per kilometer. During that same year, the first "room temperature" laser was demonstrated. Prior to that, the laser had to be cooled extensively to get any life span at all.

Early 70s The early 1970s saw lower-loss glass fiber manufactured. In 1974, fibers were produced, with a loss of less than 3 dB/km. In 1976, an ultra low loss fiber (less than 0.5 dB/km) was demonstrated. Fiber optic technology was on the verge of exploding on the world.

1976 In 1976, Illinois Bell conducted a commercial test of a Western Electric 45 Mbps system in the Chicago area. The test span was 1.5 miles long, and used 24 fibers. The test was a success. In 1977, commercial systems began to be put into use.

1983 In 1983 single mode fiber (discussed later) was introduced. As soon as the price of this much better fiber came into completion with the old multimode fiber, the floodgates opened, and fiber began to appear everywhere

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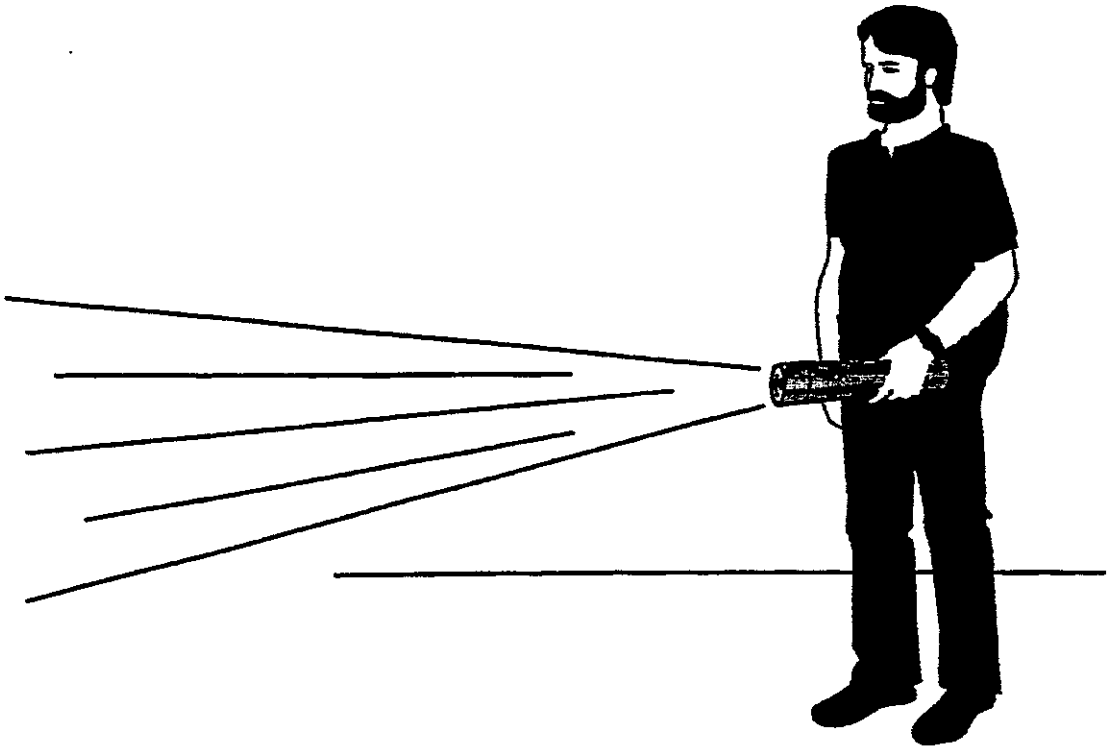

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PROPERTIES OF LIGHT

To understand the functioning of fiber optic systems, one must first understand the functioning of light, and its properties.

Light Ray

The graphic displays a light ray. The term, ray, is misleading. Light will travel in a certain direction, such as where a flashlight is aimed. However, any beam of light will begin immediately to spread out, or disperse, as shown in the illustration.

Speed

The speed of light in a perfect vacuum is 186,281 miles per second (299,793 kilometers per second). In other mediums, light will travel slower. While light of all frequencies (or wavelengths) will travel at the same speed in a vacuum, the frequencies will travel at different speeds in other materials. This causes a number of problems in the transmission of light.

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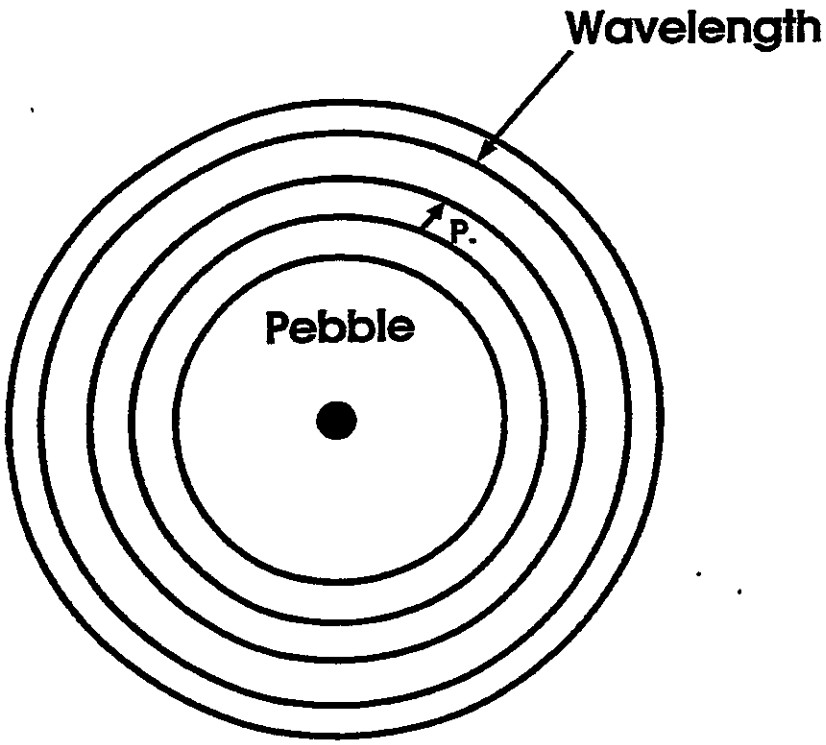
Water Waves On A Still Pond



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PROPERTIES OF LIGHT, continued

Let's look at some more properties of light. The first interesting thing is that light has many of the same characteristics as sound and electricity.

Propagation

Light has wave nature, much like water. If one were to drop a pebble into a still pond, it would create waves, as shown in the graphic. As these waves moved outward from the point of impact, they would have a speed of propagation. This is the speed that the waves travel. Propagation is the transmission of waves through air or water or some other medium.

Wavelength/ Frequency

In the analogy of the pond, the distance from one crest to another is the wavelength. The frequency of the pond waves is determined by counting the number of waves that pass a given point in a given time period.

As the frequency increases, the wavelength decreases.

This is true in radio, electricity, and waves on ponds, as well as light.

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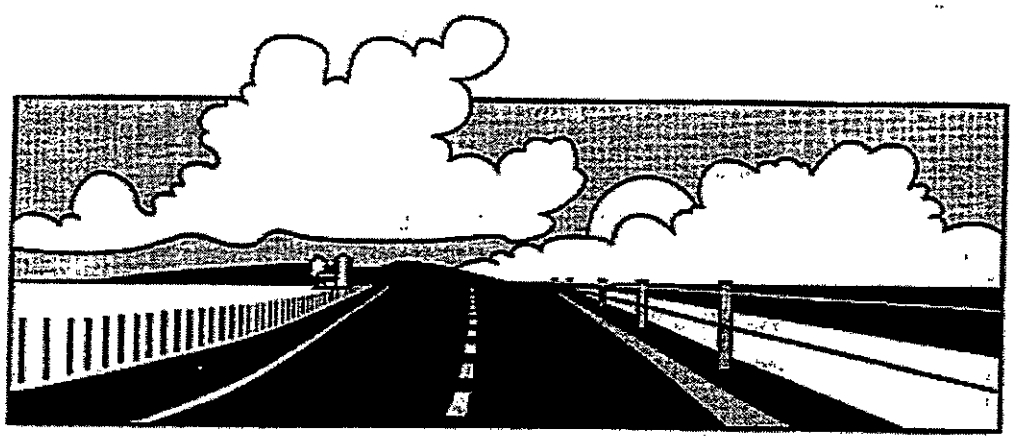

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REVIEW

1) True or false. The word, laser, is actually an acronym. I

2) All frequencies of light travel at the same rate in a vacuum, however, in other materials frequencies travel at different speeds.

3) Light has a wavy nature, much like water.

4) In the analogy of the pond, the distance from one crest to another is the wavelength.

5) Continuing the analogy of the pond, the number of waves that pass a given point in a given time period is the frequency.

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REVIEW - ANSWERS

1) True or false. The word, laser, is actually an acronym. **True**

2) All frequencies of light travel at the same in a vacuum, however, in other materials, frequencies travel at **different** speeds.

3) Light has a **wave** nature, much like water.

4) In the analogy of the pond, the distance from one crest to another is the **wavelength**.

5) Continuing the analogy of the pond, the number of waves that pass a given point in a given time period is the **frequency**.

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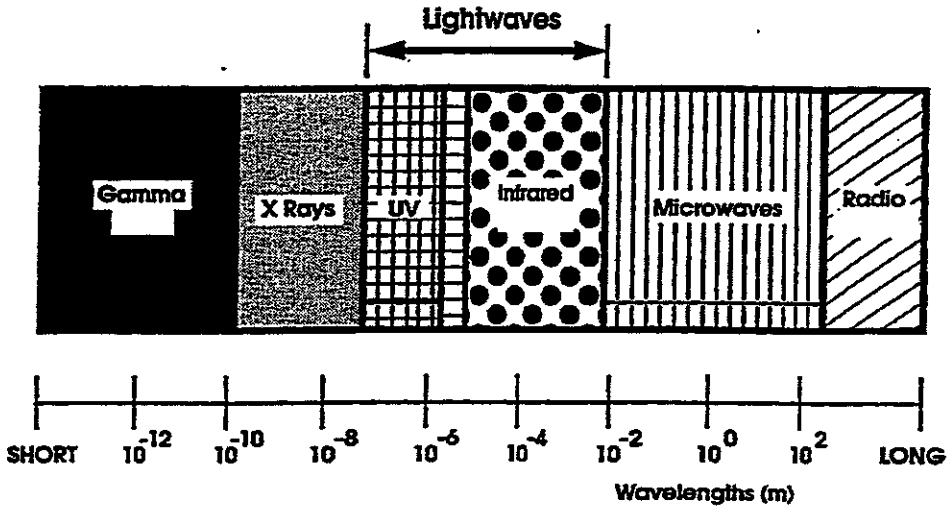
Light Is Electromagnetic Energy



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ELECTROMAGNETIC SPECTRUM

Spectrum

The graphic shows the electromagnetic spectrum. The shortest wavelengths (and therefore, the highest frequencies), are present in gamma rays. Then come the x-rays, which have longer wavelengths. Longer still are the ultraviolet rays, and then visible light. The visible light region is very small, considering the overall scale. Then we move into the infrared region. These wavelengths can be measured in the millionths and billionths of meters.

Microwaves come next. These waves are used for transmitting radio.

Next come the "short wave" radio frequencies. These are followed by the familiar commercial FM and AM radio.

FM wavelengths are in the 3 meter region. AM wavelengths are in the 300 meter region.

So, the spectrum covers a huge area, from the very short end of the scale where billions and billions of waves are in one meter, to the long radio end where one wave might be 1000 meters long. Only a small portion of the spectrum is visible light we see every day. Even though waves vary in size, they all have the same fundamental nature.

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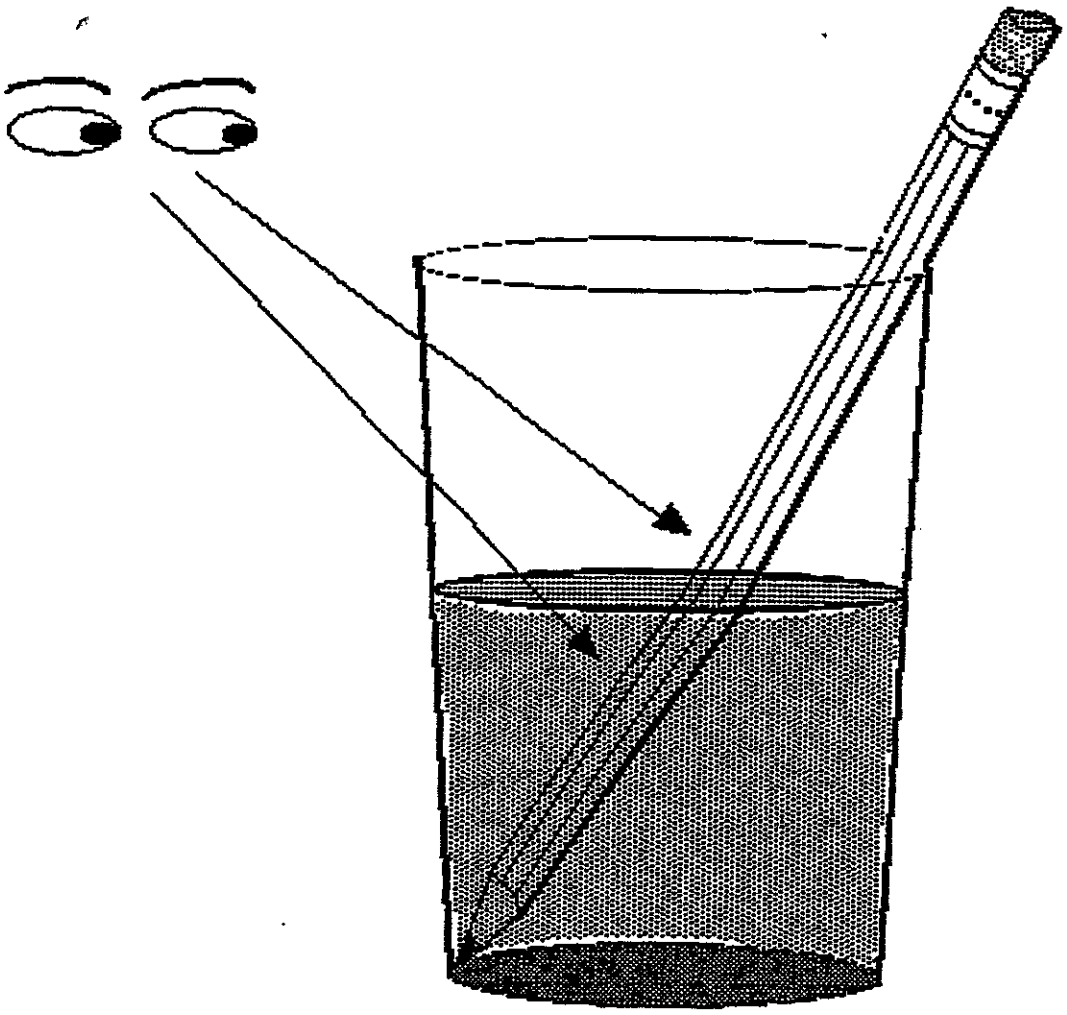
Refraction of Light

A pencil placed in a glass of water appears to bend at the point where it enters the water, due to the difference in the refractive index of water and air.



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REFRACTION OF LIGHT

Refraction is the "bending" or deflection of light as it passes from one medium into another.

When waves of light move from one medium to another, the light will become "bent."

Refractive Index

Each material has its own refractive index, which is a measure of that material's ability to bend a beam of light along a new path. A high refractive index means that the material can bend the light beam at a sharper angle.

As shown in the illustration, a pencil placed in a glass of water appears to bend at the point where it enters the water, due to the difference in the refractive index of water and air.

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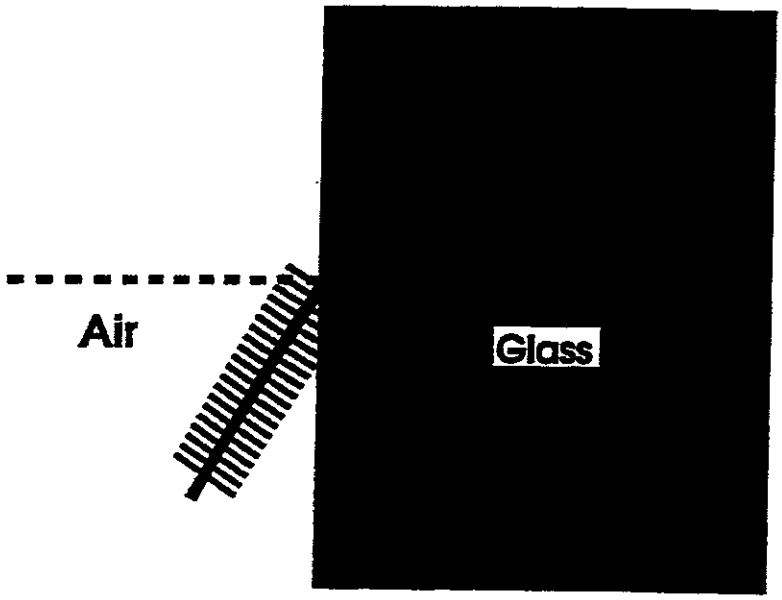
Refraction Of Light



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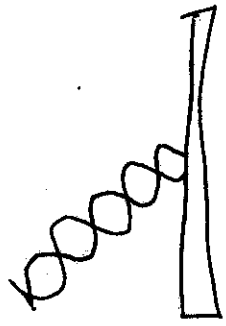
REFRACTION OF LIGHT, continued

If light enters a second medium with a higher refractive index, the light will travel slower through it.

Example

Looking at this light entering the glass in the example, we can see that the light is going to enter at an angle. If the light is presented to the glass at an angle that is less than 90 degrees, the bottom of the wave will enter the glass first. This would make the bottom of the wave slow down before the top of the wave, because the top has not entered the glass yet. This slowing effect is what causes the light to actually bend towards the dotted line.

This effect is also what causes objects under water to appear closer than they actually are. It will also cause a boat oar to appear to be bent as it enters the water.



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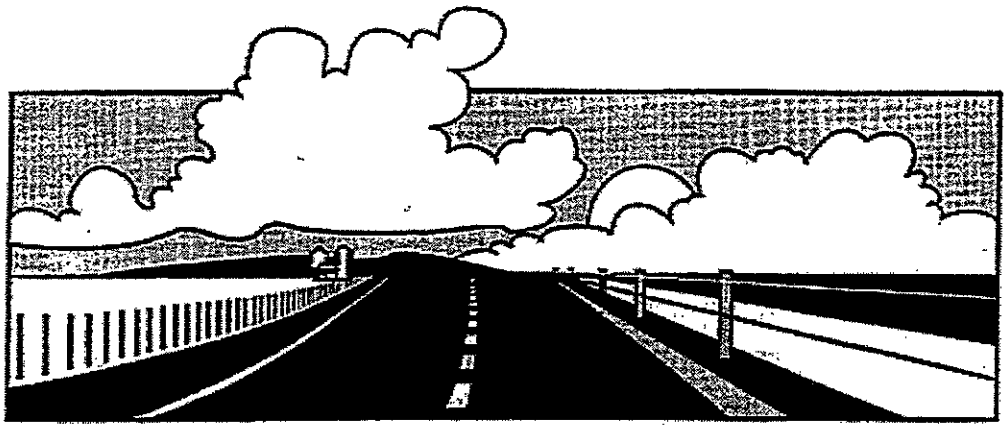

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REVIEW

1) True or false. The longest wavelengths contain the highest frequencies. F

2) The "bending" of light as it passes from one medium to another is known as refraction.

3) The measure of a material's ability to bend a beam of light is known as its refraction index.

4) Explain why a pencil appears to be bent when placed in a glass of water.
Because the light in the through the water is different than the air

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REVIEW - ANSWERS

1) True or false. The longest wavelengths contain the highest frequencies. **False**

2) The "bending" of light as it passes from one medium to another is known as **refraction**.

3) The measure of a material's ability to bend a beam of light is known as its **refractive** index.

4) Explain why a pencil appears to be bent when placed in a glass of water. **The pencil appears to bend due to the difference in the refractive index of water and air.**

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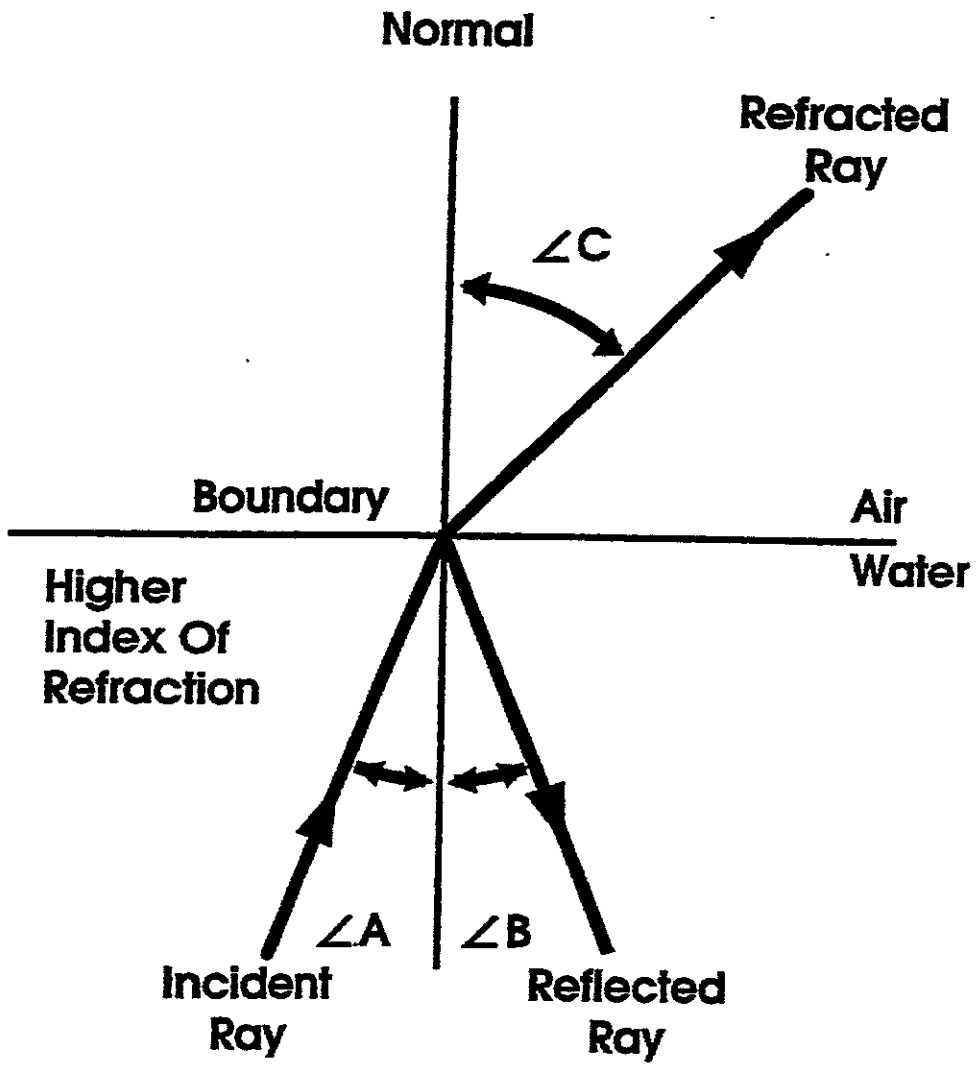

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TERMS

Let's define some terms we will be using in our study of fiber optics.

Incident Ray — The incident ray is the original light ray from a source, unbent or changed in any way.

Angle of Incidence — The angle of incidence (angle A in the diagram) is the angle between the normal line (a line drawn perpendicular to the surface), and the incident ray.

Law of Reflection — The law of reflection states that the angle of incidence (angle A) is equal to the angle of reflection (angle B).

Refracted Ray — The Refracted Ray, angle C, is in the medium of lower index of refraction (the air). Therefore, the refracted ray bends further away from the normal than the reflected ray.

Reflected Ray — The reflected ray is light which did not leave the water and enter the air. In this case, some of the light bounced off the boundary and stayed in the water. This will occur to some degree, whenever light leaves one medium to enter another.

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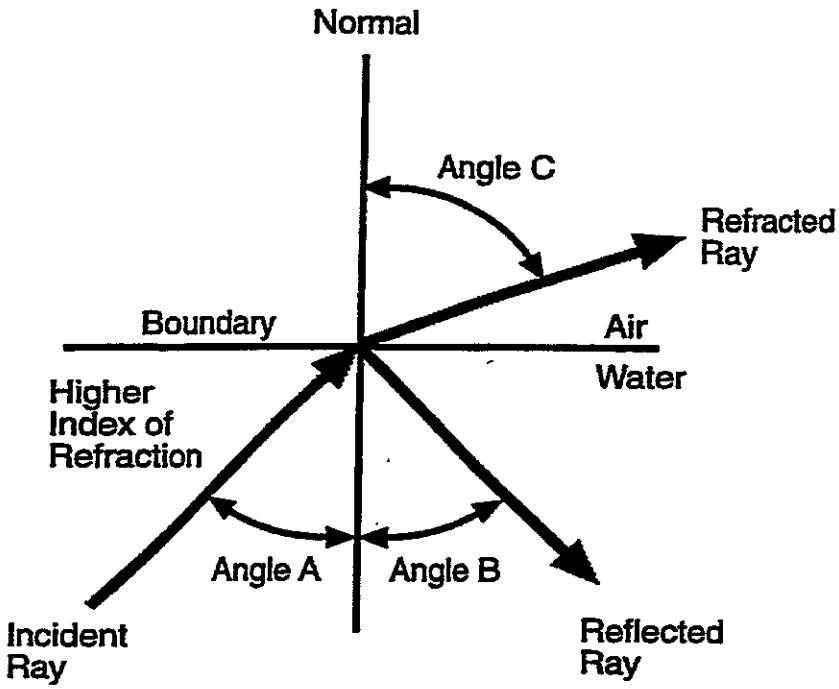

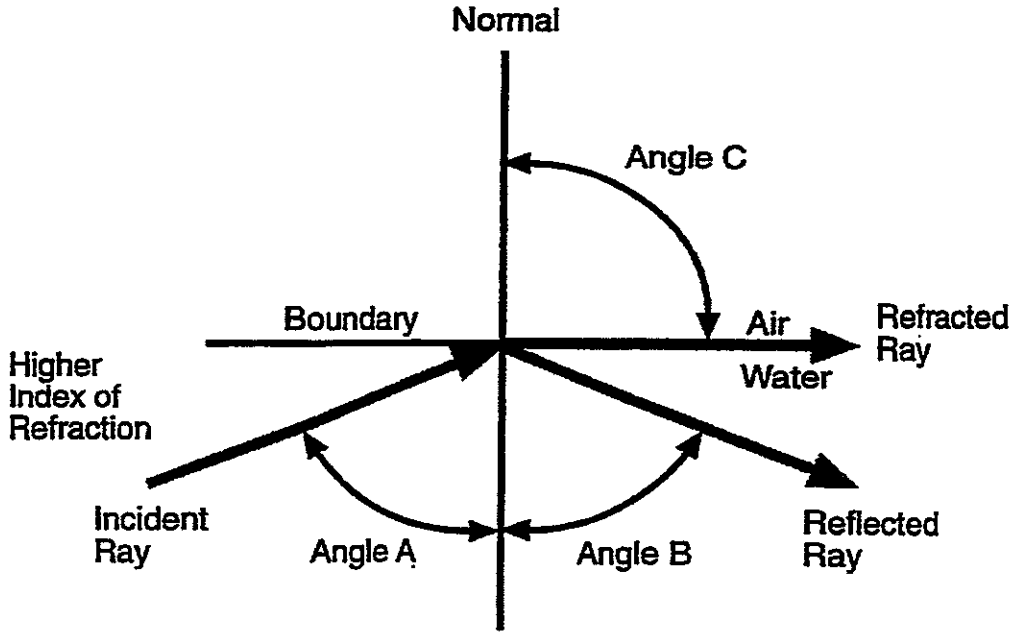

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TERMS, continued

In the top illustration, the light source has been moved in order to increase the angle of incidence (angle A). Angle B increases the same amount. As angle A increases, we can see that angle C is increasing also.

At this point, the light entering the air is being bent to a large degree.

Critical Angle

As angle A reaches a specific value called the critical angle, the refracted ray (angle C) emerges and runs right along the boundary between the air and water, as shown in the bottom illustration. At this point, no light has entered the air.

It is this critical angle that leads us to the concept of sending light through a tube of glass, through something called total internal reflection.

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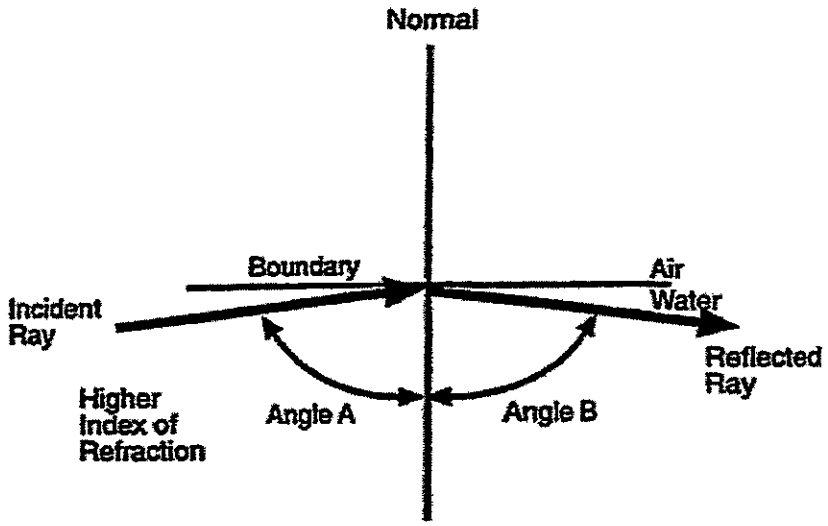
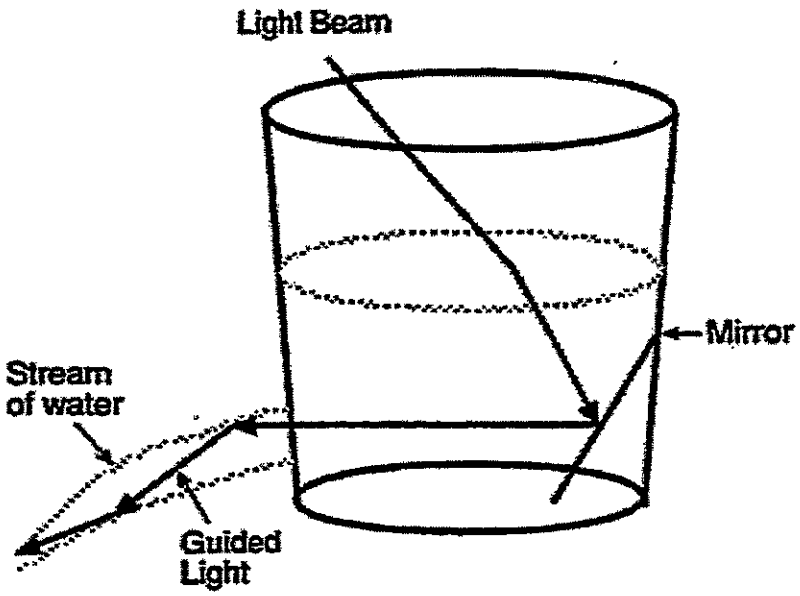


Guided Lightwave Experiment



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TERMS, continued

[redacted]

If the angle of incidence (angle A) is increased, the ray will not pass any light into the upper medium, but instead reflect totally at the boundary surface. This is called total internal reflection.

More than 140 years ago, John Tyndall, an Irishman, demonstrated that light could be guided by means of successive reflections in a stream of water. He theorized that light could be guided by total internal reflection by introducing it into a medium with a high index of refraction (like water) if surrounded by a medium with a lower index of refraction (like the air).

Verification of Principle

This can be verified with a bucket of water with a hole in it, a very strong light and a mirror (do not try this at home without proper electrical safety precautions!) If the mirror is adjusted so that the light is focused on the hole, and the water is allowed to escape through the hole, and if the surrounding room is dark enough, the light can clearly be seen being guided down the water.

This is interesting, but not too practical. We can see that the light will not exit the water, tending instead to reflect back into itself. Telephone companies do roughly the same thing today with their fiber optic systems. Fiber optic systems put light into glass and keep it inside the glass by using reflection.

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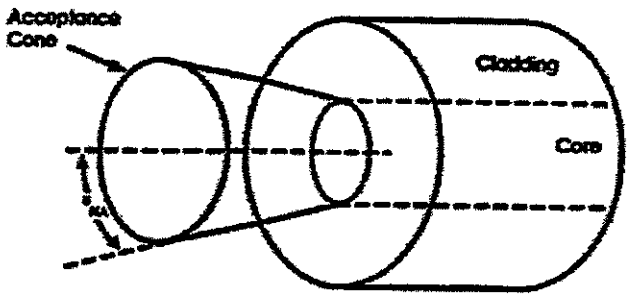
Acceptance Cone



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TERMS, continued

Let's see what happens when a beam of light is put into a fiber made of glass.

Numerical Aperture

Each piece of fiber has a "numerical aperture." This is the figure which defines how wide the input angle of the light can be, before too much loss occurs.

Acceptance Cone

The numerical aperture will define what is called the acceptance cone. Any light which is within that cone will enter the fiber and travel down the core.

Any light introduced to the fiber outside that cone of acceptance will pass through the core, into the cladding and be lost within a few inches.

Cladding

While the cladding is glass, it is not a good conductor of light. The idea is to bounce the light back into the core. If the angle is such that the light does escape into the cladding, it would travel at such a different rate of speed that there would be "echoes" at the far end. For that reason, the cladding is designed to stop any light from traveling far.

The picture shows a three dimensional view of the concept of acceptance cones. In very basic terms, the larger the numerical aperture number, the larger the acceptance cone.

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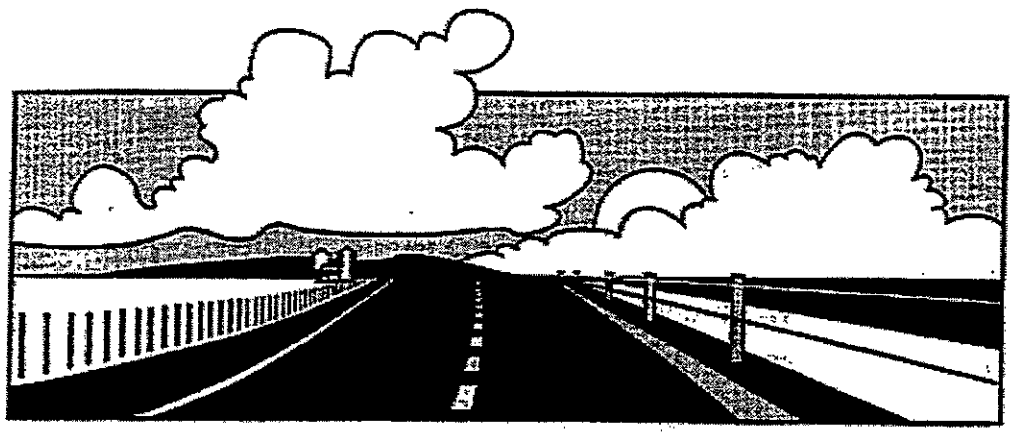

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REVIEW

1) The angle at which the incident ray tends to be reflected right along the boundary between two different materials with different refractive indexes is known as the ___b___.
   a) Angle of incidence
   b) Critical angle
   c) Refracted angle
   d) Northwest angle

2) The concept of "guiding" light by introducing it to a medium with a high index of refraction surrounded by a medium with a lower index of refraction is called ___a___.
   a) The law of reflection
   b) The refractive theory
   c) Tyndall's incidental contact theory
   d) Total internal reflection

3) The material that is designed to stop light from traveling very far is called the ___cladding___.

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REVIEW - ANSWERS

1) The angle at which the incident ray tends to be reflected right along the boundary between two different materials with different refractive indexes is known as the **(b) - critical angle**..

2) The concept of "guiding" light by introducing it to a medium with a high index of refraction surrounded by a medium with a lower index of refraction is called **(d) - total internal reflection**. .

3) The material that is designed to stop light from traveling very far is called the **cladding**.

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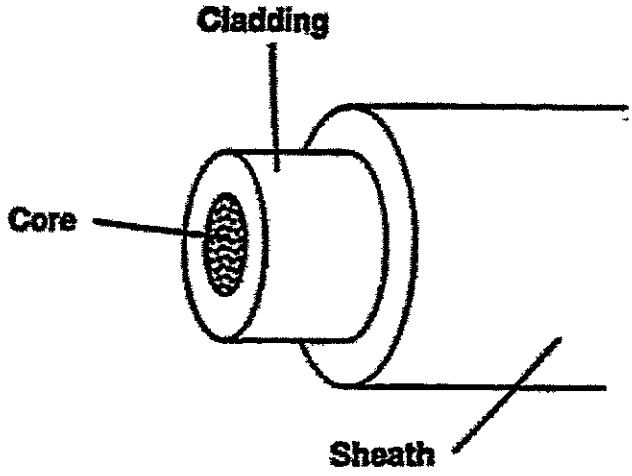
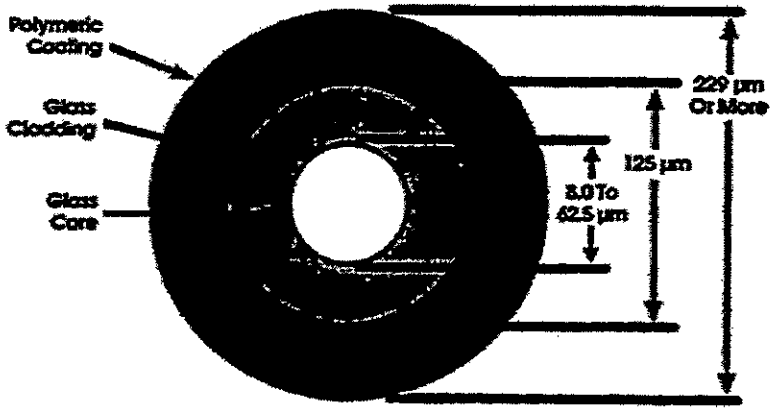
Parts of Optical Fiber



Coated Fiber Cross Section



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OPTICAL FIBER'S PHYSICAL MAKE-UP

Let's look at the actual physical makeup of this piece of [illegible] glass.

Optical fibers are made from a cylinder of glass called a preform. The fibers are typically made of layered cylinders of glass. The light guide fibers are super pure glass fibers that provide a low transmission loss path for the light signals. Individual fibers are about the size of a human hair. To make them easier to handle and protect, and more economical to install, they are combined in cables. The typical cross-section of a communications fiber is shown in the illustration.

Core

The [illegible] fiber is called the core, with another coating of glass around it called the cladding. Surrounding those two layers is the protective polymeric coating, which is nothing more than a plastic sheath. The core, made of [illegible] carrier of light.

Cladding

The cladding, which is also glass, will reflect light back into the core. The cladding has a very different refractive index than does the core. If light attempts to exit the core and enter the cladding, it will be bent back into the core. This is essentially what keeps the light in the core.

Sheath

The plastic sheath around the cladding protects the fiber during handling and cable installation. After installation, the coating of plastic will protect the glass from the elements.

Beyond all that, the polymeric coating allows the fiber to be visible. Without the color-coded plastic coating, it would be difficult to find and splice a very small piece of glass!

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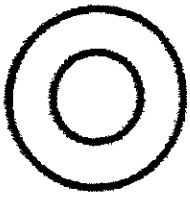
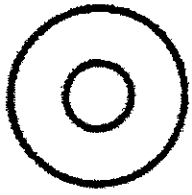
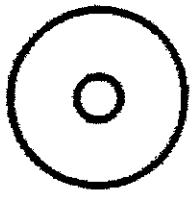
Common Fiber Types

Type	Fiber End	Cladding	Core
Multimode Step Index		140 µm	100 µm
Multimode Graded index		125 µm 125 µm 125 µm 140 µm	50 µm 62.5 µm 85 µm 100 µm
Single Mode Step Index		125 µm	8.5 µm

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TYPES OF FIBER

There are two basic types of fiber optic cable design and construction. The term, "mode," refers to the possible transmission paths of light down the fiber.

Multimode

Multimode means that there are many transmission paths for the light to travel through the fiber.

Single Mode

Single mode, which means that there is one path for the light to travel.

We will discuss three types of fiber:

- Multimode step index fiber
- Multimode graded index fiber
- Single mode step index fiber

Looking at the graphic, note that the multimode step index fiber had a very thick core (100 micrometers) and a thick cladding. This was an early fiber.

The multimode graded index fiber had a thinner core, and slightly smaller cladding. The big change came in the single mode step index fiber, where the cladding remained about the same, but the core went down to 8.5 micrometers.

Now let's examine each type in more detail.

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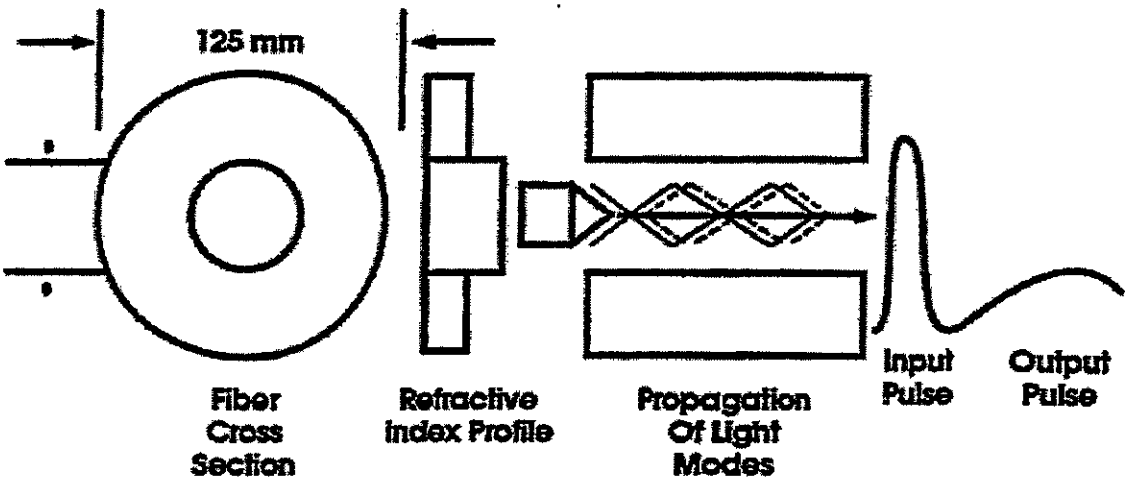
Multimode Step Index Fiber



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MULTIMODE STEP INDEX FIBER

Description

The graphic shows the picture of the old multimode step index fiber. With its 140 micrometer cladding, and 100 micrometer core, it was a relatively large fiber.

Multimode got its name from the fact that the light entering the fiber had multiple paths (or modes) to travel down. The problem with multimode was that as these multiple rays of light bounced their way down the fiber, they all arrived at the other end at slightly different times. This caused a nice, sharp input pulse to come out in a much broader, spread-out shape. In order to be able to see the output pulse clearly, the next pulse had to be held back for a while. This meant that the speeds it could transmit at were limited.

Multimode step index fiber is rarely installed in communications systems anymore, because of its very low bandwidth. These were the first fibers, and were very cheap to make, but are no longer in production. Although these fibers can still be found, they are being phased out.

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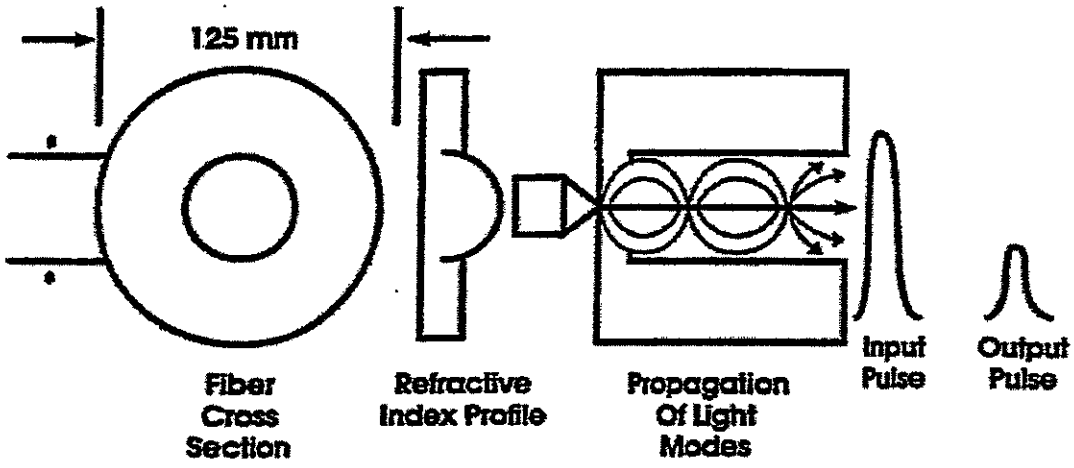
Multimode Graded Index Fiber



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MULTIMODE GRADED INDEX FIBER

Multimode graded index fiber was the next development in fiber optics. The primary benefit from these fibers was that the output pulse had about the same width as the original input, [illegible] speed.

Description

The graded index fiber had many gradually-changing indexes of glass in the core, with the index of refraction highest at the center. The index of refraction got progressively lower, further from the center. As light moves from one layer of glass to another, it is gradually bent back towards the middle.

The input pulse and the output pulse are very similar in shape, with the biggest difference being the strength.

Multimode graded index fiber is much more difficult to manufacture, due to the very complex core design, but it offers much more bandwidth than multimode step index designs. This fiber was used extensively between 1977 and 1983, but today would only be used in Local Area Networks and a few limited communications applications.

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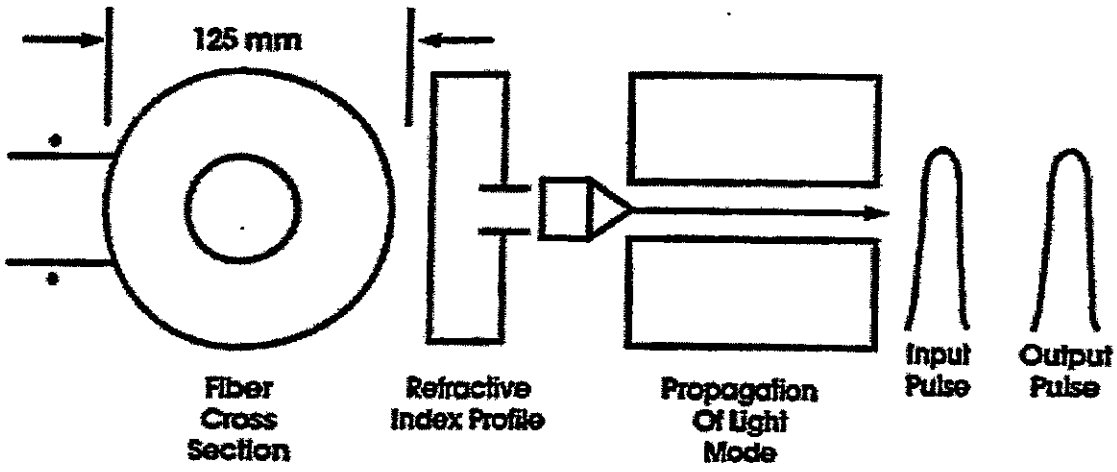
Single Mode Step Index Fiber



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SINGLE MODE STEP INDEX FIBER

Single mode fiber is the current fiber of choice. The real attraction of this fiber is that it had the capacity for very large communications systems. Today's systems transmit well over one *BILLION* bits per second. Much higher speeds can be expected in the near future.

Description

Single mode fiber gets its name from the fact that the core is so small that there is only one path for the light to travel down. The very small core makes coupling light into the fiber more difficult, but once the light is in the core, it all goes right down the middle, as shown in the graphic. This makes the output pulse very similar to the input both in terms of pulse shape, and strength.

Single Mode Step Index

Single mode step index fiber requires a very high degree of precision manufacturing, due to the very tight dimensional tolerances required. It has the potential of being the cheapest to make, yet still have the largest capacity. Estimates say that developments in light sources could make this type of fiber have virtually unlimited bandwidth.

Even though the single mode fiber is a very good method of transmitting information, there are still some drawbacks to it. These effects that will be found in any piece of fiber, and must be dealt with. Let's look at some of the difficulties in fiber cables themselves.

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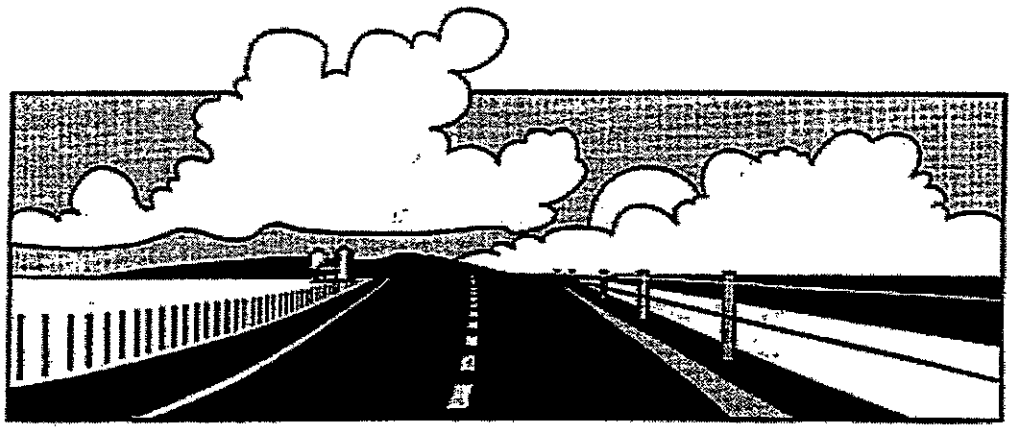

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REVIEW

1) In optical fiber, the carrier of light is the Core.

2) In optical fiber, the Cladding has a different refractive index that will bend light back into the core.

3) In optical fiber, the Sheath provides protection during handling, protection during cable installation, and protection from the elements

4) Put a check beside the statements that apply to single mode step index fiber.

- ✓ Currently the fiber of choice.
- ✓ Many paths for the light to travel down the fiber.
- ✓ Input and output pulses are very similar
- ✓ Requires precise manufacturing.
- ✓ Most expensive to make of the fiber types.
- ✓ May have virtually unlimited bandwidth.

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REVIEW - ANSWERS

1) In optical fiber, the carrier of light is the **core**.

2) In optical fiber, the **cladding** has a different refractive index that will bend light back into the **core**.

3) In optical fiber, the **sheath** provides protection during handling, protection during cable installation, and protection from the elements.

4) Put a check beside the statements that apply to single mode step index fiber.

✔	Currently the fiber of choice.
_____	Many paths for the light to travel down the fiber.
✔	Input and output pulses are very similar
✔	Requires precision manufacturing.
_____	Most expensive to make of the fiber types.
✔	May have virtually unlimited bandwidth.

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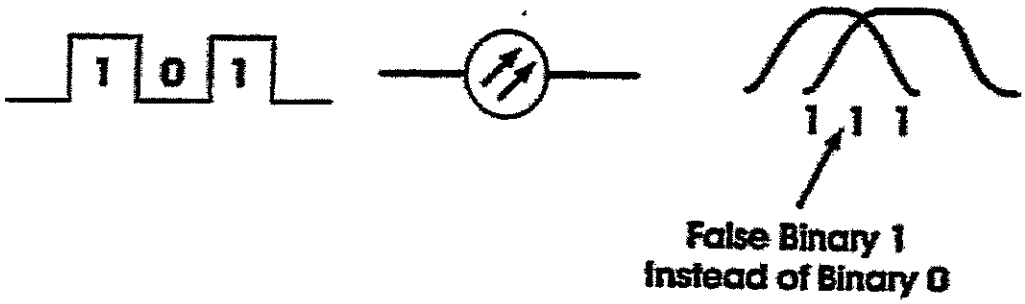
Pulse Dispersion Effects



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DISPERSION

Pulse Dispersion

The picture shows the effects of something called pulse dispersion. This pulse spreading, or delay dispersion, causes the pulses of light on the fiber to begin to spread out and widen. The binary "101" seen on the left will gradually broaden out until it would appear to be a "111" at the distant end.

The dispersion problem is mainly the result of two effects: modal dispersion, and chromatic dispersion.

Modal Dispersion

The light spreading as it travels the different modes of a fiber cable causes modal dispersion. Since different modes are required for this to occur, there is not any modal dispersion in single mode cable. (If there is only one mode, all the light must be traveling in the same mode.)

Multimode graded index fiber lessens the modal dispersion problem since all the various modes will arrive at the receive end close to the same time. This limits, but does not eliminate dispersion.

Multimode step index fiber suffers the worst damage from this type of dispersion. Since the cable is all one index of glass, and there are so many different modes, modal dispersion limits the applications for this type of glass. The longer the cable, the worse the problem.

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Chromatic Dispersion

One of the ways to deal with the chromatic problem is to use the purest light source possible.

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CHROMATIC DISPERSION

Chromatic dispersion is the second problem found on all fiber systems. When an optical source creates light, it does not create a "pure" light. A pure light would emit one frequency (or color as it is called, since light is visible). Instead, the light source will emit several or even hundreds of frequencies, depending on the quality of the light source.

Effect

When these frequencies are emitted, they begin to travel down the fiber at slightly different speeds. When they arrive at the far end, they have "spread" the pulse again. The more spreading of pulses that goes on, the slower the transmission speed must be, on that link.

Cures

One of the cures (or attempts to cure) for the problem is to use the purest light source available. In this case, as is normal in most things, quality costs money. If the cheaper Light Emitting Diode (LED) is used, telephone companies can expect more variation. The more expensive laser will vary much less, depending on the frequency being transmitted.

More on these two important components later.

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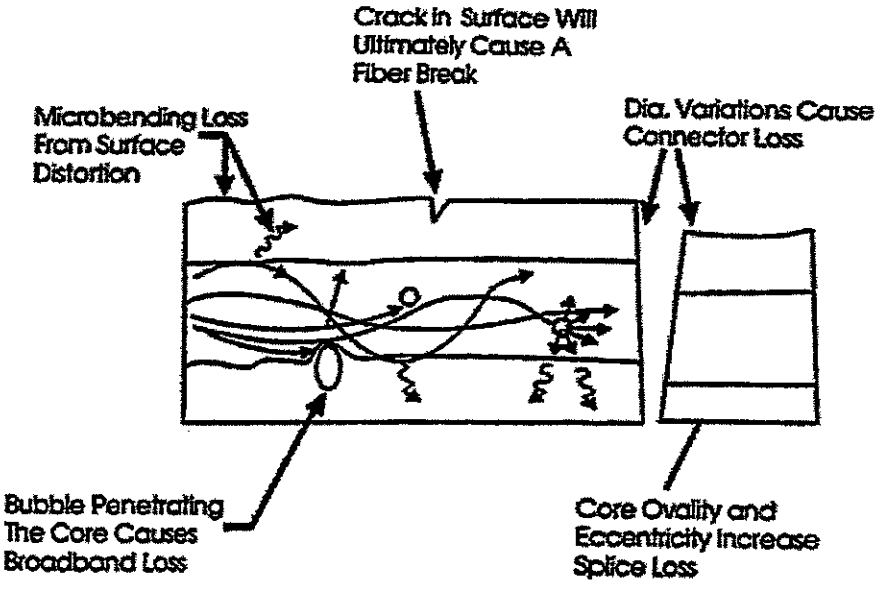
Structural and Compositional Problems


Crack in Surface Will Ultimately Cause A Fiber Break
Microbending Loss From Surface Distortion
Dia. Variations Cause Connector Loss
Bubble Penetrating The Core Causes Broadband Loss
Core Ovality and Eccentricity Increase Splice Loss

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TRANSMISSION LOSS

Scattering Loss

Another problem found on fiber optic cable is scattering loss. This is caused by variations in the size of the fiber core. The process of manufacturing and creating cables may cause the fiber to be stressed over small bumps or may cause imperfections in the cable material.

These imperfections are called micro bends.

Splicing Loss

When two reels of fiber are spliced together, the possibility exists that the cross section or gauge of the cables will not be exactly the same. When spliced, the smaller cable will reflect light back into the larger one. Strange as it seems, this can be a one way problem. If spliced so that the smaller cable is transmitting into the larger one, there will be no additional loss at the splice. If, however, the larger cable is transmitting into the smaller, loss will occur.

A good analogy is that of a water pipe. A small pipe pouring into a larger pipe is not a problem But a large pipe pouring into a smaller one can cause a loss of water.

Any ovality, or out of roundness, occuring during manufacture will cause loss when the cable is spliced.

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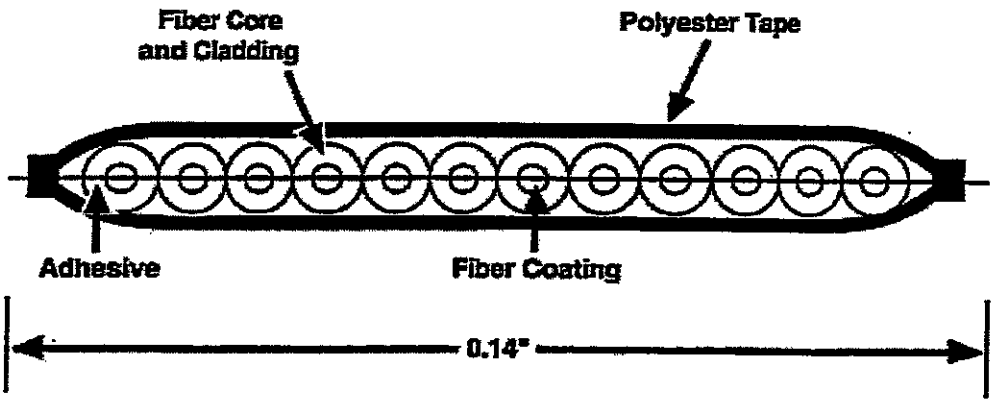
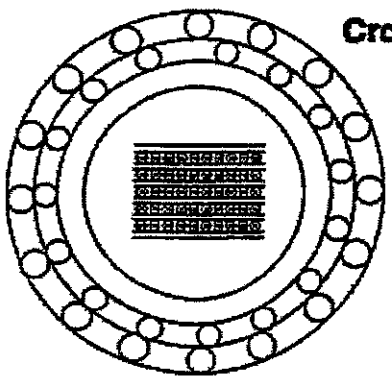
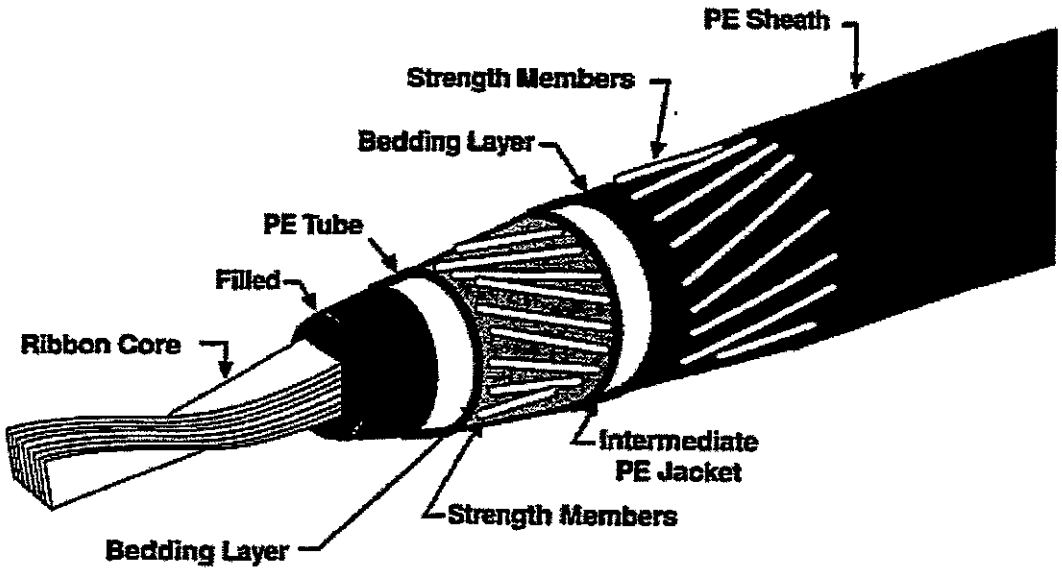
Ribbon Design Fiber Optic Cable







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FIBER OPTIC CABLE DESIGN

Two designs of widely used fiber optic cable are:

- Ribbon design
- Stranded design

Both of these designs use different splicing methods.

Ribbon Design

In fabricating ribbon design fiber optic cable, 12 individual fibers are sandwiched between 2 layers of tape. Up to 12 of these ribbons can be stacked in a bundle, which becomes the core of the cable.

After the ribbons have been stacked, a cable sheath is then built around the core. The finished cable is cut to the specific length required by the customer and is then terminated with array-type connectors. The illustration shows only one type of many ribbon-type cables available.

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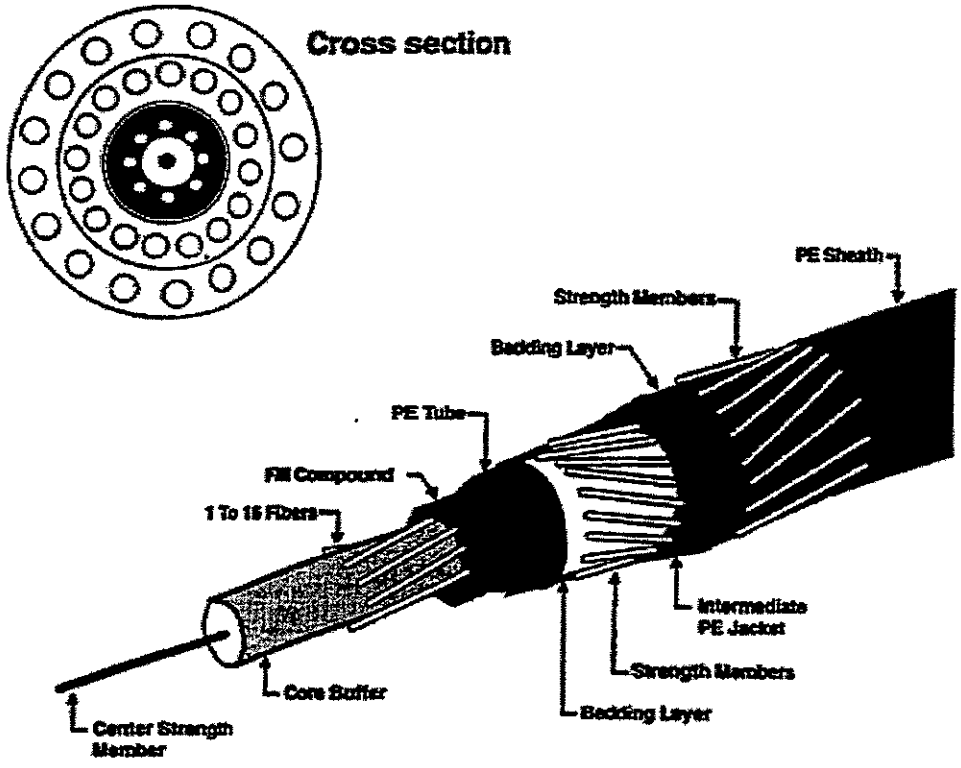
Stranded Fiber Cable



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FIBER OPTIC CABLE DESIGN, continued

Stranded Design Fibers, on a single unit type stranded cable, lay around the perimeter of the core buffer. The example shows only one type of many stranded fiber cables.

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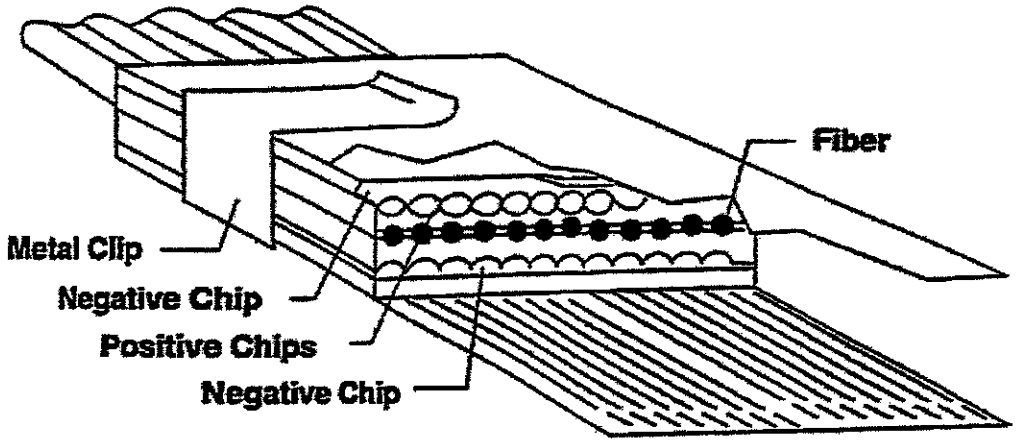
Splicing



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SPLICING

Mechanical Splicing

Fiber array connectors are often applied to both ends of the fiber ribbon cable prior to shipment from the factory. These connectors reduce the time and effort required for splicing in the field.

Fiber array connectors can also be applied to ribbons in the field during installation of the cable, or later during repair.

Many other types of mechanical splices are available from different manufacturers for stranded design cables.

Fusion Splicing

In fusion splicing, the fibers are cleaned, cut and positioned with the aid of a microscope. An electric arc is used to fuse the two fibers together.

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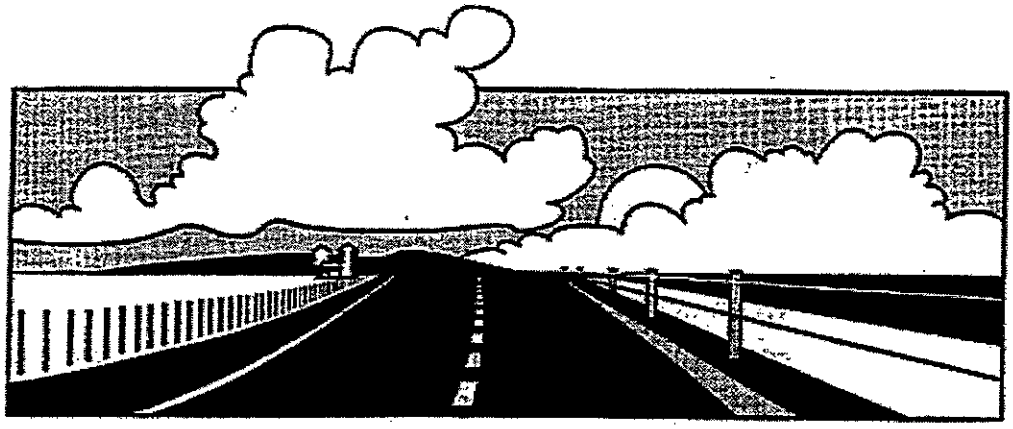

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REVIEW

1) Match the following type of fiber transmission loss with its appropriate description.

Chromatic dispersion c
Modal dispersion d
Splicing Loss b
Scattering Loss a

a) Caused by manufacturing imperfections and variations in the size of the fiber core.

b) Caused when two reels of fiber with unlike cross-sections are spliced together.

c) Caused by impure light sources that emit different frequencies of light

d) Caused by light spreading out as it travels through different modes of fiber cable.

2) Provide an explanation for the following types of fiber optic cable:

Ribbon design cable
12 fibers sandwiched between layers of coating, stacked to form the core of a larger ~~cable~~ sheathed cable.

Stranded design cable
Fibers that are stranded around an inner-core, with a sheath around it.

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REVIEW - ANSWERS

1) Match the following type of fiber transmission loss with its appropriate description.
Chromatic dispersion **(c)**
Modal dispersion **(d)**
Splicing Loss **(b)**
Scattering Loss **(a)**

2) Provide an explanation for the following types of fiber optic cable:
Ribbon design cable
Individual fibers are sandwiched between two layers of tape called a ribbon; the ribbons are stacked in a bundle in the middle of the cable.
Stranded design cable
Fibers lay around the perimeter of the core buffer of the cable.

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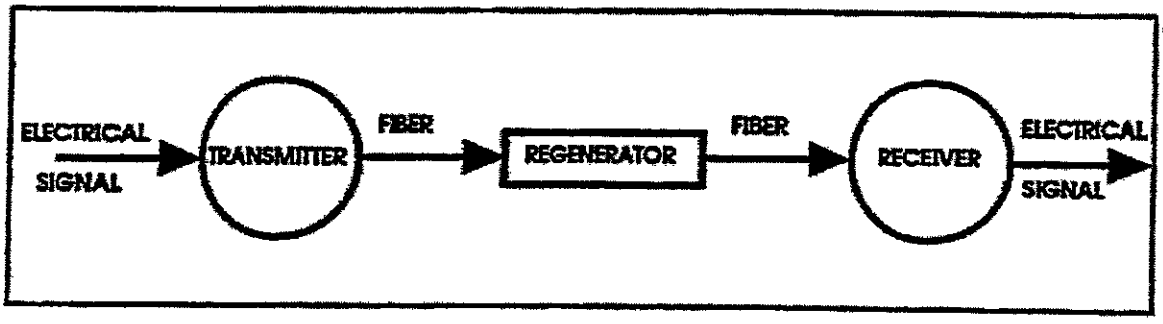
Basic Fiber Optic System



Basic components of a fiber optic system:

- Optical fiber
- Optical transmitter
- Optical receiver
- Optical regenerator

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BASIC SYSTEM COMPONENTS

Optical System

The basic components of a fiber optic system are:

- Optical fiber
- A light source, or transmitter
- A light detector, or receiver
- Optical regenerators, as needed

As we've looked at the makeup of optical fiber, let's look at the other components of the fiber optic system in more detail.

Optical Transmitter

The light source, or transmitter, is modulated - turned on or off - in response to an electrical signal. This produces pulses of light or digital optical signals.

These signals are transmitted through the optical fiber.

Optical Receiver

Light exiting the fiber is received by a light receiver or detector, and converted back into an electrical signal.

Optical Regenerator

In between the transmitter and receiver is the optical regenerator, which rebuilds the digital signal, like a line repeater. However, regenerators on fiber lines can be spaced at far greater distances than line repeaters and may not even be needed on some spans.

Now let's look at each of these in a little more detail.

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Comparison of LEDs and Lasers

	LED	LASER
Source Size	Large	Small
Beam Pattern	Wide	Narrow
Temperature Sensitivity	Tolerant	Very Sensitive
Reliability	1,000,000 Hours	200,000 Hours
Coupling Loss	15 dB	3 dB
Modulation Rate	100 Mbps	2.4 Gbps

1,000,000 Hours = 114.2 years

200,000 Hours = 22.8 years

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LIGHT TRANSMITTERS

We'll start with a look at the source which will create the light, the transmitter.

Transmitter Types

When selecting a transmitter, two choices are available: Light Emitting Diodes (LED's) and the laser. Each of these has its pluses and minuses, as shown in the chart.

Laser

The laser is smaller, and has a much narrower beam pattern. It couples with very low loss onto the glass, and has a very small spectral width. This means that it sends out only one or two frequencies of light. The modulation of a laser today is well over two billion bits per second, and that rate will only increase. On the negative side, the laser is expensive, very sensitive to heat and cold, and has a life span of 200,000 hours.

LED

The LED is larger in size, has a wide beam pattern, and couples poorly to the fiber. It also emits many frequencies around the pilot frequency. It can modulate to several million bits per second. On the positive side, it is cheap, can withstand heat and cold and has a life expectancy around five times that of the laser.

Each of these sources has their own use. In a Central Office where the environment is controlled, lasers can be installed and get higher speeds and longer distances between the regenerators. In an uncontrolled climate, the telephone company might choose to sacrifice speed for the more durable LED.

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Detector Comparison

PIN	APD
➢ Less sensitive	➢ More sensitive
➢ Low power	➢ High power
➢ Less expensive	➢ More expensive

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LIGHT RECEIVERS

On the other end of this fiber system, something has to receive the light. This is the job of the receiver, or detector.

Functions

Receivers typically provide the following functions:

- ❒ Detection of the incoming optical signal
- ❒ Optical to electrical conversion
- ❒ Signal regeneration

Factors

The main factors affecting receiver performance include:

- ✦ Sensitivity
- ✦ Operating wavelengths and materials
- ✦ Optical noise
- ✦ Bandwidth

There are two choices of detectors.

Detector Types

The Positive Intrinsic Negative diode (PIN) is the cheaper of the two and is a less sensitive receiver. The Avalanche Photo Diode (APD) is a more sensitive unit, but it is more expensive.

When we discuss sensitivity, we are talking about the ability to receive a weak signal, and still convert it to the proper electrical voltage. The PIN is less sensitive, and can cause more signal errors, but it is also less expensive. It is also more durable.

The APD is much more sensitive, and can recreate the signal from less incoming light. This allows longer spans between regenerators, thereby saving money. It also has a very high power output, and must be kept cool.

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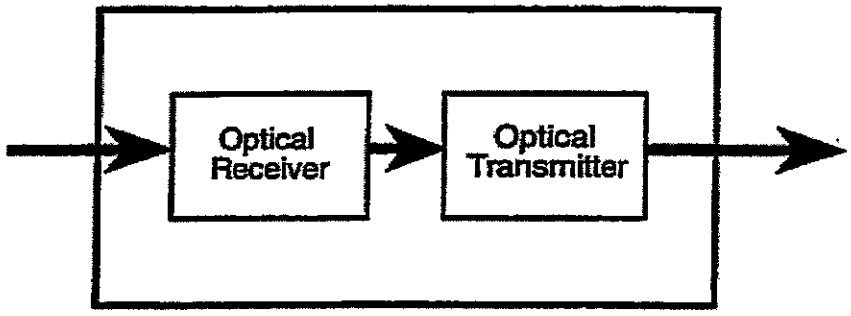
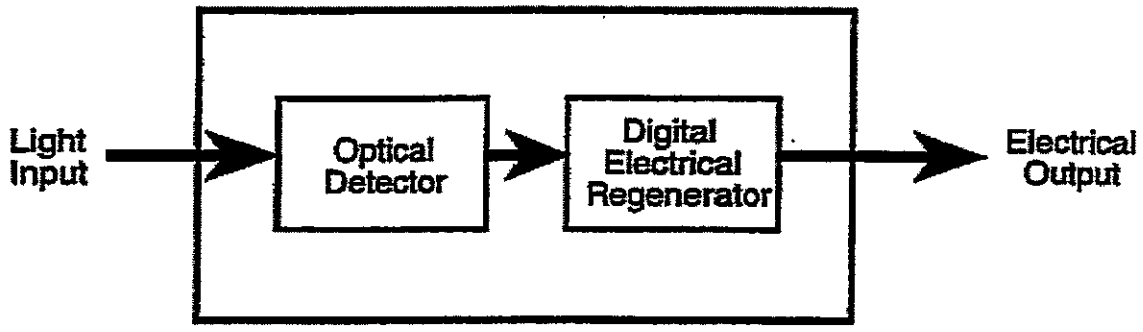
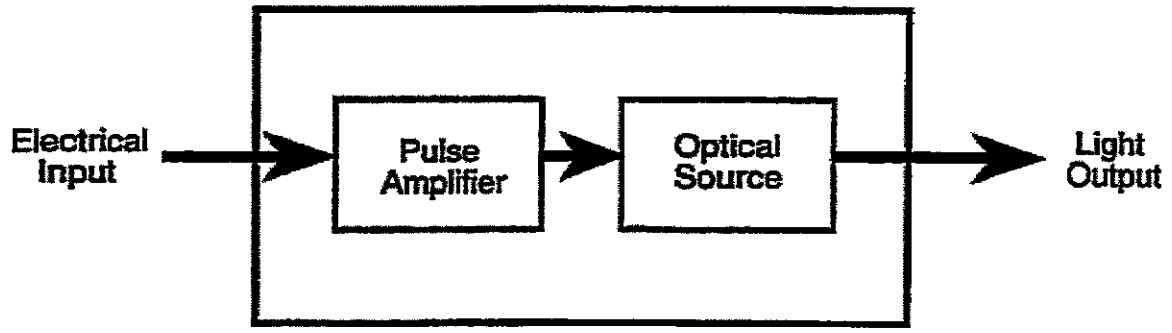
Optical Regenerator System



Optical Receiver



Optical Transmitter



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OPTICAL REGENERATORS

Function

Located on the transmission line between the light transmitter and detector is the regenerator, or repeater. Pulses of light suffer degradation due to the loss and dispersion characteristics of the fiber as the pulses travel down the fiber. The job of the regenerator is to rebuild the signal.

Description

The optical regenerator system shown in the top diagram is a device made up of a receiver and a transmitter.

Optical Receiver Function

The optical receiver shown in the middle diagram takes the light input and converts the light signal to an electrical representation of that signal. The digital electric regenerator takes the electrical signal, rebuilds it, and passes it to the optical transmitter.

Optical Transmitter Function

The optical transmitter in the bottom diagram converts the electrical signal into a stream of light pulses and launches this stream into the next section of fiber.

Several manufacturers are working on a system that would regenerate the light signal without converting to an electrical signal. This would simplify things considerably.

Factors

The spacing of these regenerators is one of the important considerations in the design of a system. Each system will be different. Some of the factors to be considered include:

- ✦ The bit rate of the system.
- ✦ Light source selected.
- ✦ Detector selected.
- ✦ Type of fiber selected.

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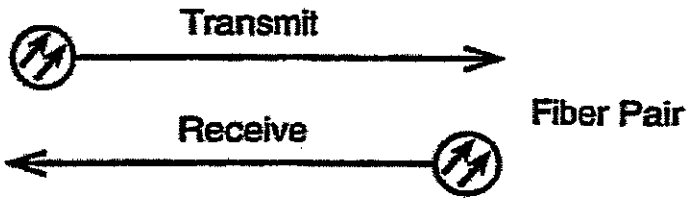
Fiber Pair



One regenerator.....one direction

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FIBER OPTIC CABLE IN AN OPTICAL SYSTEM

Fiber Pairs

Nearly all fiber optic systems use unidirectional transmission, whereby one fiber will only handle one direction of transmission. Therefore, it takes two fibers per system: one transmitting fiber and one receiving fiber. This is called a fiber pair.

Protection

Fiber optic systems use a "protected facility." This means that if we have two fiber pairs in a cable, one pair will carry service and the other pair will be equipped, but idle. If the working pair suffers a failure or serious degradation, service is automatically switched to the protection pair.

Regenerators

Regenerators are one-way devices; they work in one direction on a single fiber.

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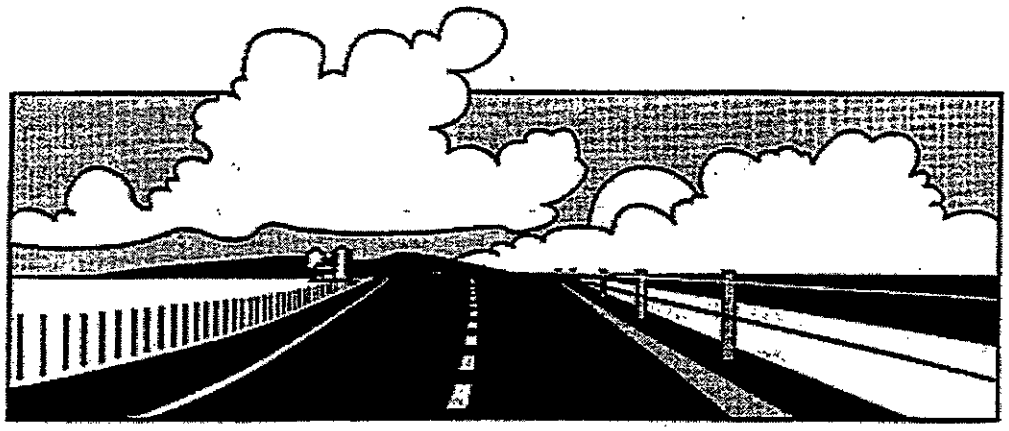

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REVIEW

1) List the four components of a basic fiber optic system.
   a) optical fiber
   b) transmitter
   c) receiver
   d) regenerators

2) In the spaces provided, write LED or Laser in the space opposite the description.
   - Led — Wide beam pattern
   - Led — Sends one or two frequencies of light
   - Laser — Expensive
   - LED — Can withstand heat and cold
   - LED — Couples poorly to the fiber
   - Laser — Modulates at over two billion bits per second

3) The job of the optical regenerator is to regenerate the signal.

4) One fiber handles one direction of transmission.

5) It takes two fibers per system: the receive fiber and one transmit fiber.

6) Fiber optic systems use a "protected facility." Explain what this means.
   protected pair

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REVIEW - ANSWERS

1) List the four components of a basic fiber optic system.
   a) **Optical fiber**
   b) **An optical transmitter**
   c) **An optical receiver**
   d) **An optical regenerator**

2) In the spaces provided, write LED or Laser in the space opposite the description.

LED	Wide beam pattern
Laser	Sends one or two frequencies of light
Laser	Expensive
LED	Can withstand heat and cold
LED	Couples poorly to the fiber
Laser	Modulates at over two billion bits per second

3) The job of the optical regenerator is to **rebuild** the signal.

4) One fiber handles **one** direction of transmission.

5) It takes two fibers per system: the **transmitting** fiber and one **receiving** fiber.

6) Fiber optic systems use a "protected facility." Explain what this means. **If a working fiber pair suffers a failure or degradation, service is automatically switched to a protection pair.**

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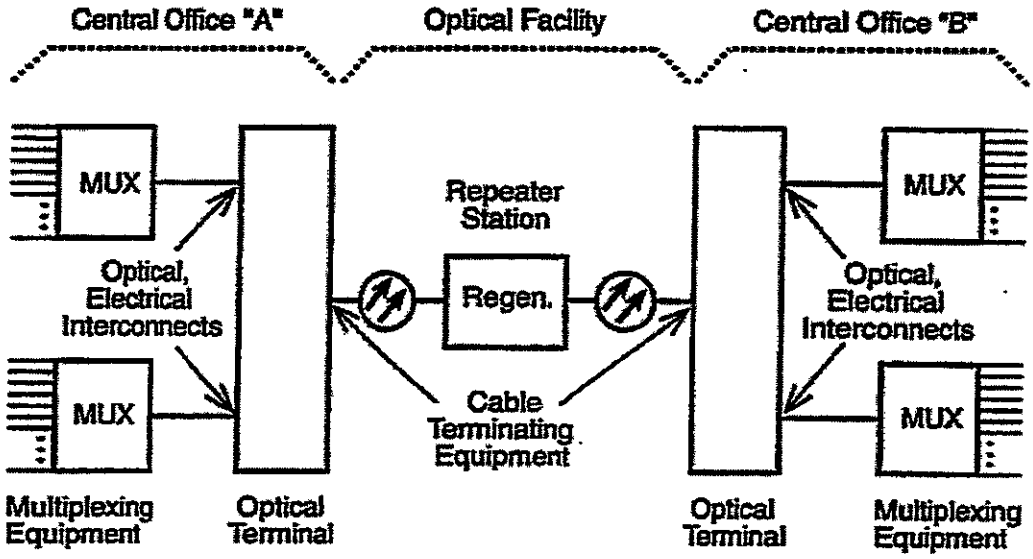
Fiber Optic Equipment



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FIBER OPTIC EQUIPMENT

Major Components

Major component groups of the fiber optic system include Central Office equipment, repeater station equipment, and fiber optic cable. For what follows next, also refer to page 90.

C.O. Equipment Functions

The generic Fiber Optic Terminal (FOT):

- ✦ Converts electrical signals to optical signals in the transmitting direction and optical to electrical signals in the receiving direction.
- ✦ Multiplexes and demultiplexes signals between DS3 and higher rate digital signal levels.
- ✦ Retimes and reshapes the digital pulse stream
- ✦ Delivers a standard digital signal level to a cross-connect point.

C.O. Equipment Components

The following components are required to perform these functions:

- ✔ An optical transmitter that includes a light source such as an LED or laser diode.
- ✔ An optical receiver, usually a Positive Intrinsic Negative (PIN) diode or Avalanche Photo Diode (APD).
- ✔ Electronics to regenerate the received signal.
- ✔ Electronics to convert the regenerated optical signal to the desired electrical signal (DS3) for the multiplex equipment.

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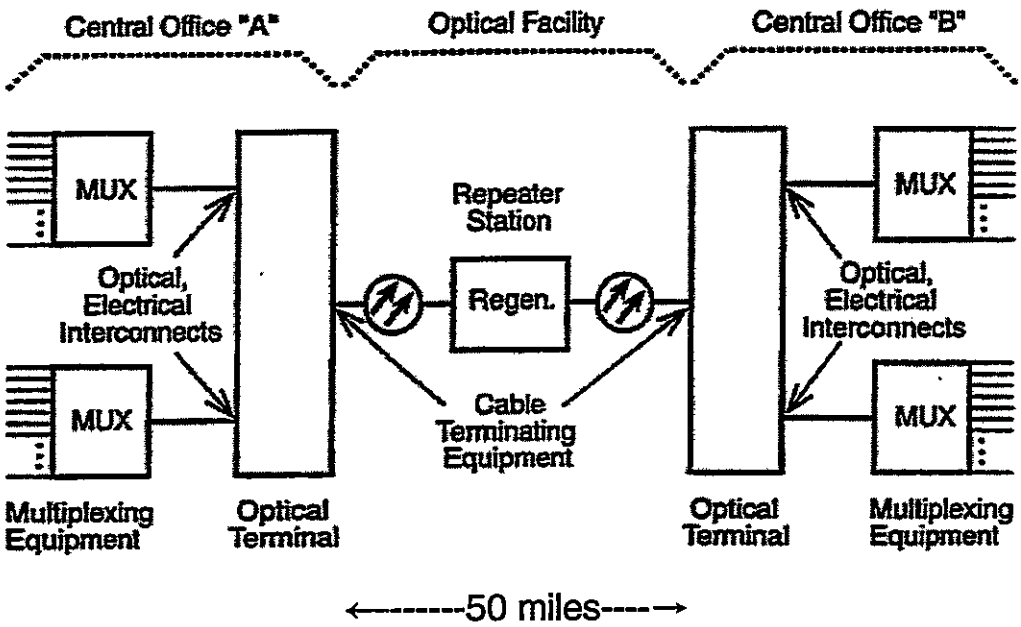
Repeater Station Placement



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FIBER OPTIC EQUIPMENT – continued

Repeater Station

Repeater (regeneration) station equipment consists of an optical receiver, regenerator and transmitter.

Presently, most systems will transmit about 50 miles without regeneration.

This distance will become drastically longer with pending technology advances.

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Fiber Distribution Frame (FDF)

- ✔ Small Office Configuration
  - ★ Less than 576 incoming fibers
  - ★ Fiber Splice Shelves on FDF
  - ★ No Fiber Splice Frame
  - ★ Must be within 50 feet of fiber entrance facility

- ✔ Large Office Configuration
  - ★ More than 576 incoming fiber fibers and more than one FDF
  - ★ One or more Fiber Splice Frame required
  - ★ MIC type cabling used in office
  - ★ Must be within 50 feet of fiber entrance facility

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FIBER DISTRIBUTION FRAME

General Description

A Fiber Distribution Frame (FDF) provides for a Central Office interface between outside plant fiber cables or intrafacility fire retardant cable, (commonly referred to as MIC type cable) and equipment cables, using patch cords in a fiber optic system.

Fiber Splice Shelf

Fiber splice shelves are always used in conjunction with a FDF, to terminate incoming cables. These shelves are located either in a separate Fiber Splice Frame (FSF) or at the bottom mounting locations of the FDF.

Fiber Splice Frame

For a large office configuration, with more than 576 incoming fibers, a Fiber Splice Frame is required. For less than 576 incoming fibers, a CO does not require a FDF.

The Fiber Splice Frame or the Fiber Distribution Frame must be within 50 feet of the fiber entrance facility or cable vault.

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Digital Hierarchy

Level	DS1	Pay Load	Bit Rate	Voice Circuits	Transmission System	Ref
DS0	0	-	64 Kbps	1	Elect	*
DS1	1	24XDS0	1.544 Mbps	24	Elect	*
DS1C	2	48XDS0	3.152 Mbps	48	Elect	*
DS2	4	96XDS 0	6.312Mbps	96	Elect	*
DS3	28	28XDS1	44.736Mbps	672	Elect&Optical	*
DS3C	56	2XDS3	90.52Mbps	1344	Elect&Optical	*
DS4	168	6XDS3	274.176Mbps	4032	Elect&Optical	*
STS-1	28	1XDS3	51.84Mbps	672	Elect	**
OC-1	28	1XDS3	51.84Mbps	672	Optical	**
STS-3	84	3XDS3	155.52Mbps	2016	Elect	**
OC-3	84	3XDS3	155.52Mbps	2016	Optical	**
STS-12	336	12xDS3	622.08Mbps	8064	Elect	**
OC-12	336	12XDS3	622.08Mbps	8064	Optical	**
STS-48	1344	48XDS3	2.48832Gbps	32256	Elect	**
OC-48	1344	48XDS3	2.48832Gbps	32256	Optical	**
STS-192	5376	192XDS3	9.95328Gbps	129024	Elect	**
OC-192	5376	192XDS3	9.95328Gbps	129024	Optical	**

***Asynchronous signal**
**** Synchronous SONET signal**

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DIGITAL HIERARCHY

Let's revisit the digital hierarchy again. This time, the chart shows an expanded version that also includes the Synchronous Hierarchy defining the bit rates and formats for Synchronous Optical Network (SONET) signals.

Note how at the higher bit rates, the transmission system used is exclusively fiber optics.

SONET

At this point, it is important to recognize that a SONET will transport all existing signals of the digital hierarchy, ISDN and Broadband ISDN signals. SONET based network elements are being deployed with optical interfaces, using Virtual Tributary Groups (VT) and Synchronous Transport Signal (STS-*n*) levels to establish an efficient architecture of managing high capacity fiber optic links.

STS and OC Level Signals

The Synchronous Transport Signal - One (STS-1) level is the basic bit module used to build SONET signals. It has a line bit rate of 51.84 Mbps. The STS-1 electrical interface signal may be converted to an Optical Carrier-One (OC-1) level signal.

STS bit rate of 51.84 Mbps may be multiplexed with other modules to form a higher STS or bit rate, which can then be converted to an OC at a higher bit rate.

Example: STS-3 electrical at 155.52 Mbps, or Optical Carrier - Three (OC-3) level is the result of multiplexing basic module bit rate of 51.84 Mbps times 3.

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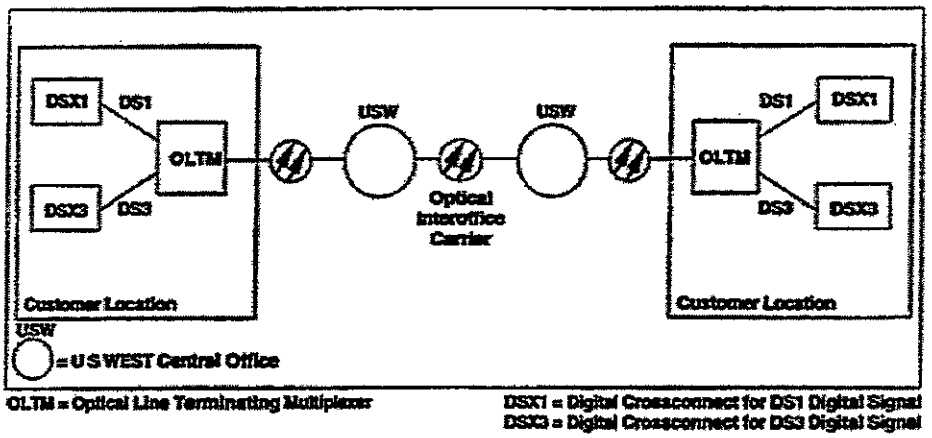
U S WEST Fiber Optic Services



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U S WEST FIBER OPTIC SERVICE

General Description

U S WEST offers fiber optic DS1, DS2, DS3 service to its business customers. These fiber optic services provide high-speed, high capacity, point-to-point digital transmission capability between customer locations.

The standard offering is finished-terminated service, which means that all intermediate and terminating equipment is provided by U S WEST. The customer has access to the service via standard electrical interfaces.

Speeds

Each application will be delivered to the customer in electrical form at specified speeds. Each service is custom designed, and offered under contract.

The minimum purchase is 1.544 Mbps (DS1 or T1). Other offerings include:

- DS1C (3.152 Mbps)
- DS2 (6.312 Mbps)
- DS3 (44.736 Mbps)
- Higher speeds are possible.

Installation

The installation includes the fiber optic elements discussed earlier; the optical fiber, the light source and the light detector, and a regenerator, if necessary.

The illustration shows the basic design. The total number of additional components required to serve the customer will depend on the application.

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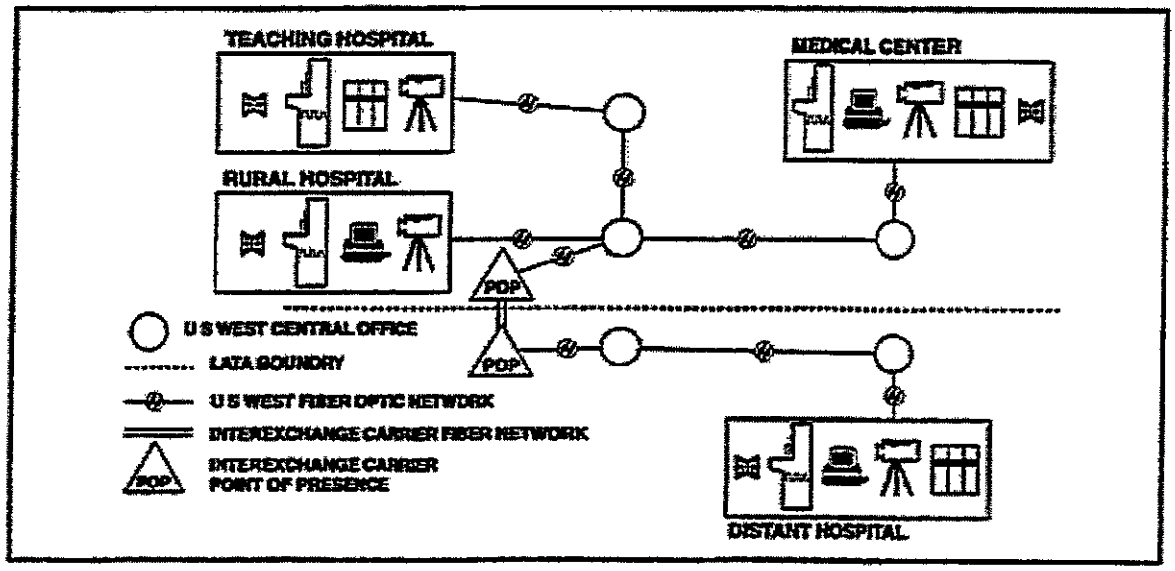
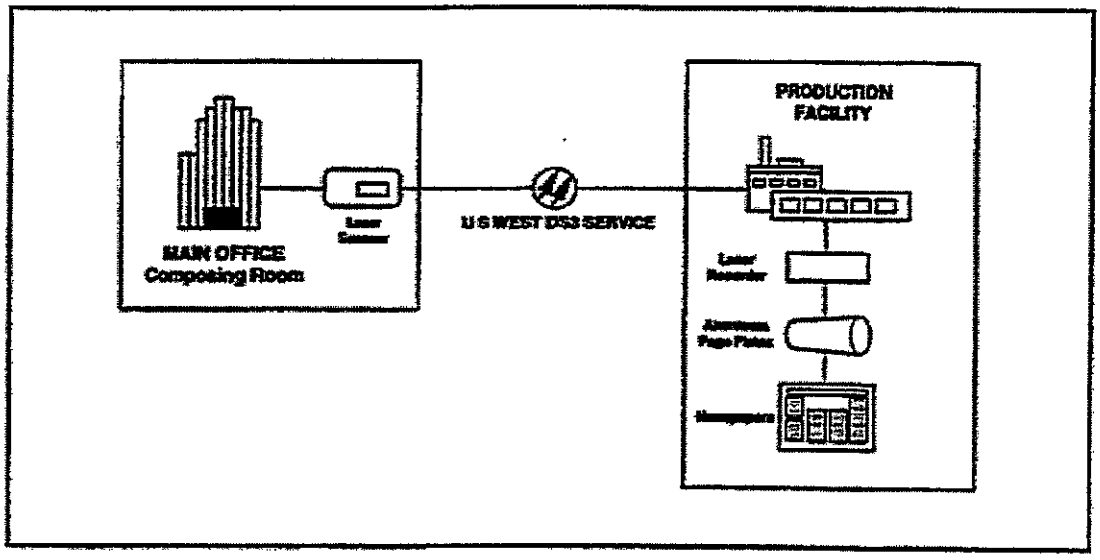
Application Examples

Distance Learning



Remote Printing



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U S WEST FIBER OPTIC SERVICE, continued

Standard Features

Standard Features are as follows:

- ✔ A high quality optical transmission system.
- ✔ State of the art terminating electronics.
- ✔ Experienced design support from U S WEST.
- ✔ 24 hour maintenance, with local expert technicians.
- ✔ Leased bandwidth in multiples of DS1 or DS3.

Optical Features

Optional Features include automatic protection switching.

Applications

Fiber optic service services a wide range of data communications applications. Common applications include:

- ☆ Bulk data/file transfer (mainframe computer to mainframe computer)
- ☆ Interconnecting digital PBXs
- ☆ High speed facsimile links
- ☆ Distance learning
- ☆ Remote laser printing
- ☆ Video
- ☆ Video conferencing
- ☆ Graphics

Examples

The illustrations show two examples of applications: a distance learning application and a remote printing application.

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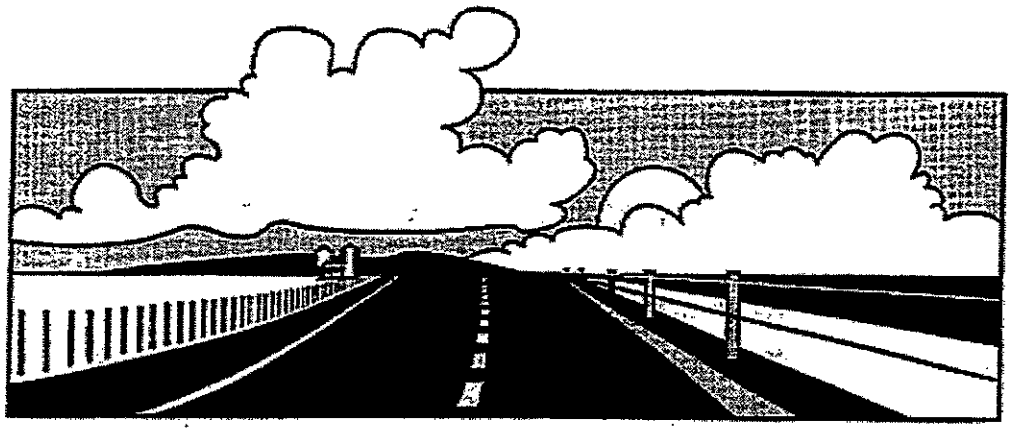

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REVIEW

1) Match the fiber optic equipment term with its description.

Cable terminating equipment C	(A) Takes a number of lower speed channels and combines them to form one higher speed channel.
Optical/electrical interconnects B	(B) Link the multiplexers and lightwave transmitters/receivers together with optical terminal fibers.
Multiplexing equipment A	(C) Provides the transition between outside plant cables and optical terminal fibers.
Optical terminal D	(D) Converts electrical-to-optical and optical-to-electrical signals and delivers the signal to the cross-connect point.

2) U S WEST Fiber Optic service is finished-terminated service, which means that all intermediate and terminating equipment is provided by U S WEST.

3) U S WEST Fiber Optic Service is custom designed and offered under Contract.

4) List at least two applications for U S WEST Fiber Optic Service.
Video conferencing, PBXes interconnects

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REVIEW - ANSWERS

1) Match the fiber optic equipment term with its description.
Cable terminating equipment **(C)**
Optical/electrical interconnects **(B)**
Multiplexing equipment **(A)**
Optical terminal **(D)**

2) U S WEST Fiber Optic service is finished-terminated service, which means that all **intermediate** and **terminating** equipment is provided by U S WEST.

3) U S WEST Fiber Optic Service is **custom** designed and offered under **contract**.

4) List at least two applications for U S WEST Fiber Optic Service.
Any two of the following are acceptable (or others you may have thought of): **bulk data transfer (mainframe computer to mainframe computer); interconnecting digital PBXs; high speed facsimile links; distance learning; remote laser printing; video; video conferencing; graphics.**

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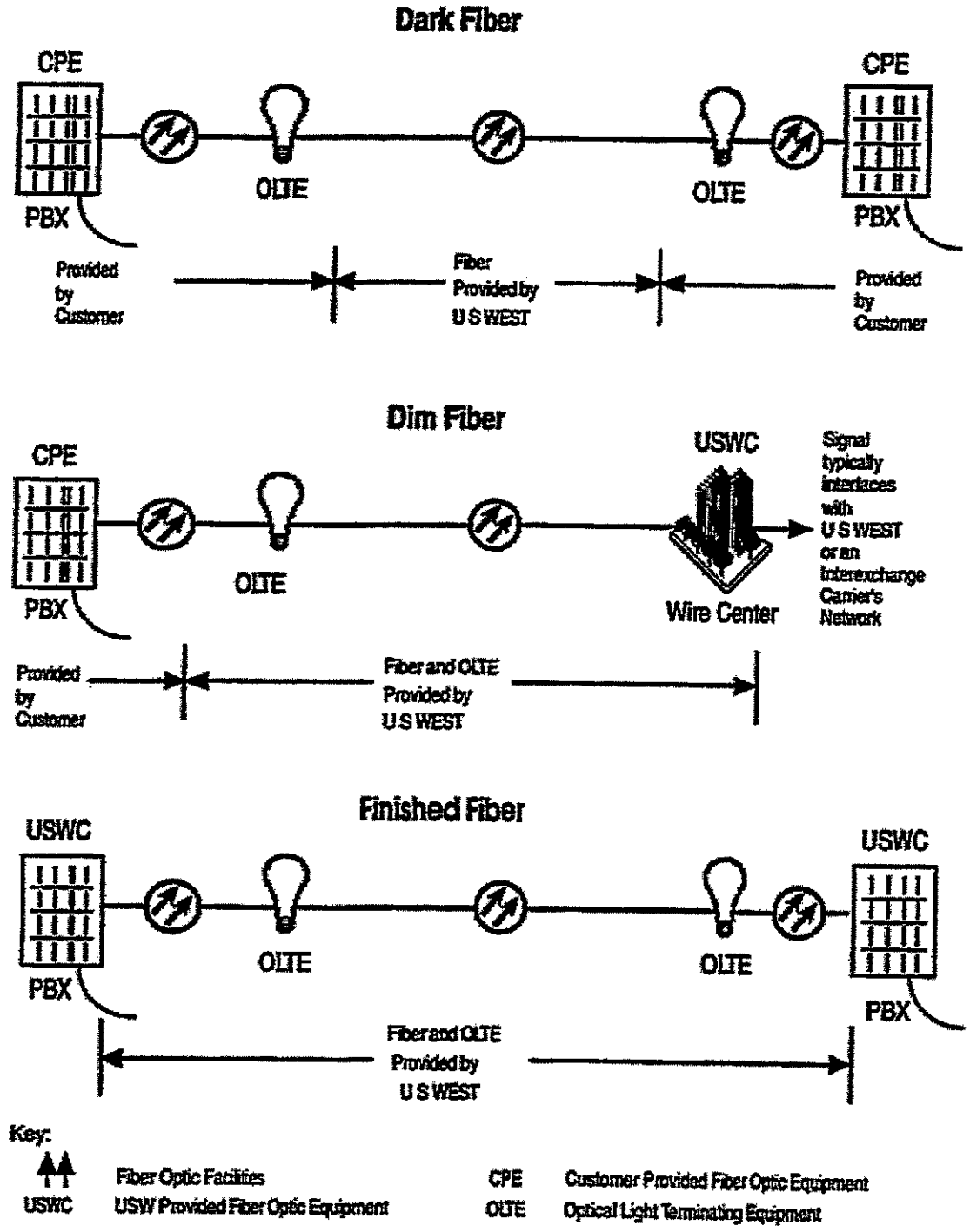
Three Basic Fiber Applications



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BASIC FIBER APPLICATIONS

There are three basic fiber applications offered by U S WEST: dark fiber, dim fiber and finished-terminated fiber.

Dark Fiber

[redacted] without the usually accompanying transmission service. It is referred to as "dark" because it is sold without light transmission. The customer is expected to furnish the electronics, signal and light source. Because of this, the customer can control the speed with which information is sent. On a traditional digital line, the price is based on speed of transmission. Because of this, sale of dark fiber requires special CEO approval. Points of this service:

- U S WEST provides the fiber
- The customer provides the CPE, and the light transmitter, light detector and the conversion from light to an electrical signal (collectively called the Optical Line Terminating Equipment, or OLTE.)
- With the application, the signal is typically relayed between two customer locations.

Dim Fiber

Dim Fiber terminates in a Wire Center where U S WEST can control the speed. Points of this service include:

- U S WEST provides the Fiber and OLTE.
- The customer provides the CPE.
- The signal typically interfaces between the customer location and a Wire Center to an interexchange Carrier.

Finished/ Terminated Fiber

U S WEST provides all intermediate and terminating equipment and offers an electrical signal to the customer. The signal typically interfaces through U S WEST.

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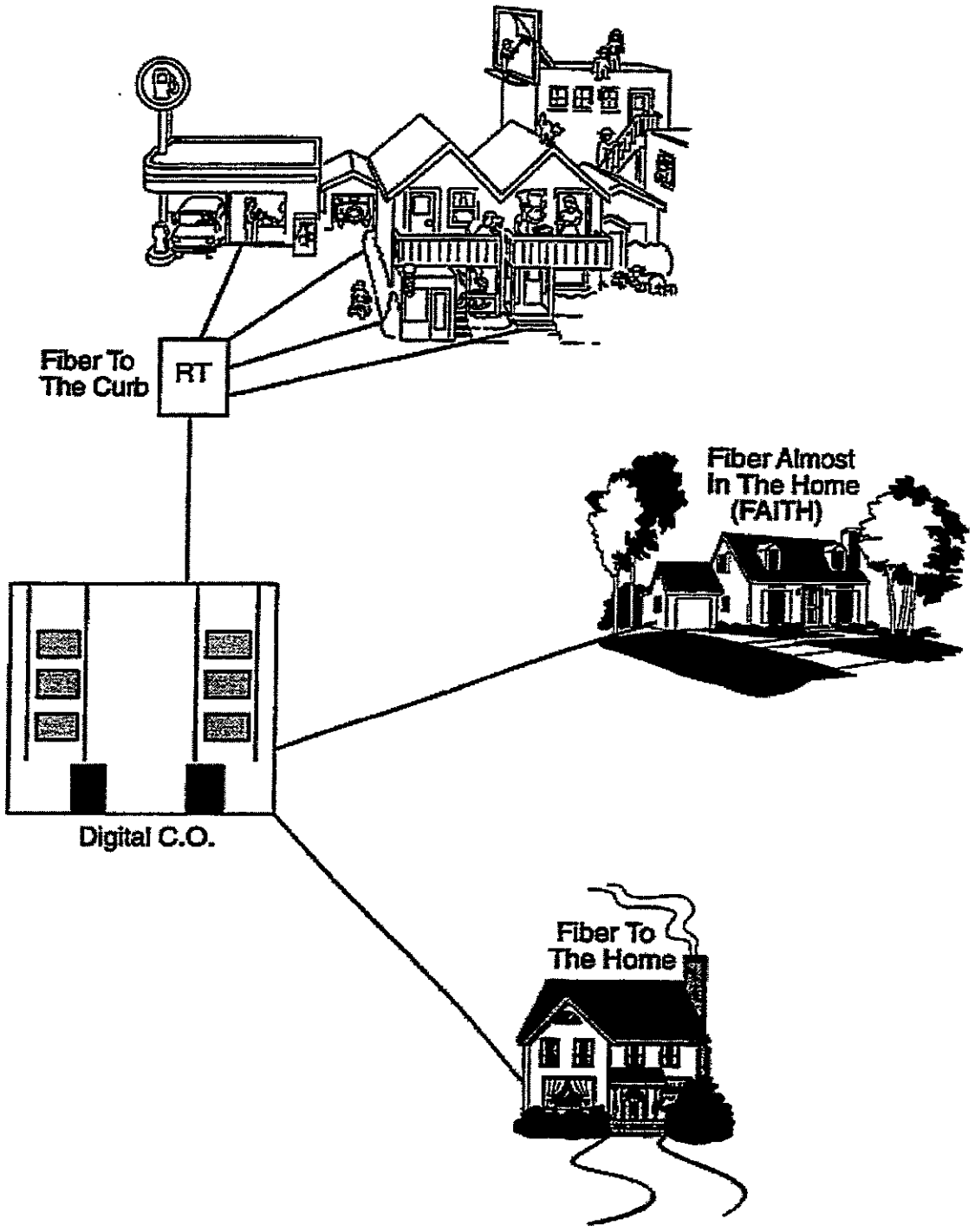
Fiber to Where?



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FIBER LOOP DEVELOPMENTS

Fiber in the local loop is an accepted idea, the question being when and by whom. The cable T.V. industry is interested. The RBOCs are very interested. Will the RBOCs become "cable TV" providers, or will cable TV companies provide dial tone?

Formats

Fiber is visualized as coming to the local loop in one or more of the following formats:

- FTTH - Fiber To The Home. Fiber would actually terminate in the subscriber's premises; each location would need optical transmitting and terminating electronics.
- FTTC - Fiber To The Curb. Fiber would terminate in the subscriber's general area, and then coaxial cable or wire would carry the signal to the premises. This would work much like Subscriber Loop Carrier does today.
- FAITH - Fiber Almost In The Home. This refers to terminating the fiber in the garage, etc. (Remember, the optical terminating equipment might not match your living room décor!)

It goes without saying that the analog impediments to the digital signal disappear with the installation of fiber to the home and office. The bandwidth, resistance, reflection and bridge tap problems do not exist to any degree with fiber. Distances of 45 to 60 miles from the Central Office to the Network Termination would not pose problems.

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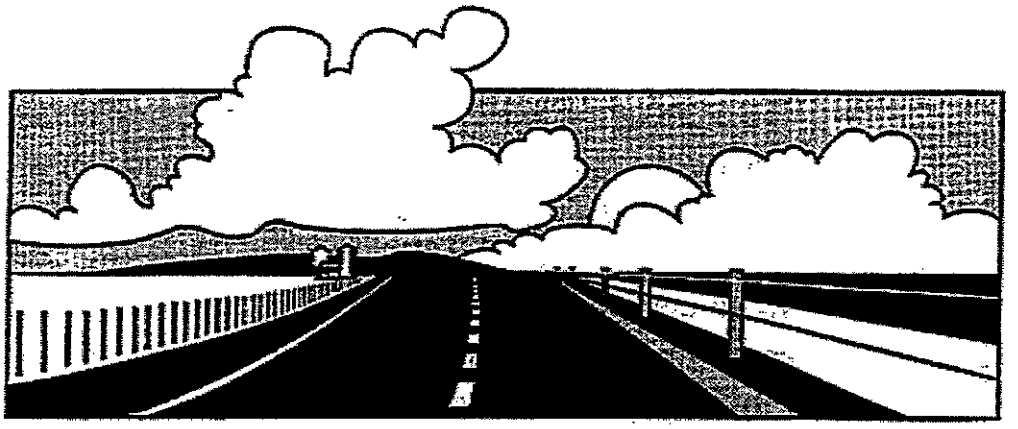

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REVIEW

1) With dark fiber, who is expected to furnish the electronics, signal and light source? Customer

- U S WEST
- The customer
- The customer and U S WEST

2) What does U S WEST provide with Finished-Terminated Fiber? a) all of above

- All intermediate equipment
- All terminating equipment
- An electrical signal to the customer
- All of the above

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REVIEW - ANSWERS

1) With dark fiber, who is expected to furnish the electronics, signal and light source? **The customer**.

2) What does U S WEST provide with Finished-Terminated Fiber? **All of the above**

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This concludes Part E

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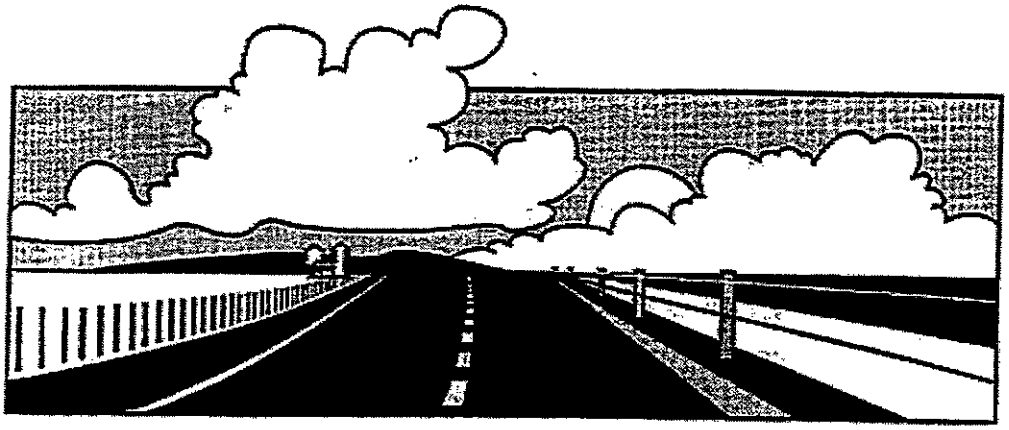

Proceed to Part F

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Table of Contents

PART F: INTEGRATED SERVICES DIGITAL NETWORK 107
PURPOSE AND PREVIEW 107
Purpose 107
Preview 107
INTRODUCTION 109
Advantages 109
WHERE WE ARE TODAY 111
Today 111
WHERE WE'LL BE TOMORROW 113
Tomorrow 113
INTEGRATED SERVICES DIGITAL NETWORK (ISDN) 115
Consumer Factors 115
ISDN Definition 115
ISDN - FACTORS 117
Standards 117
Factors 117
REVIEW 119
ISDN CONCEPTS 123
Goal 123
Phase-in 123
Compatibility 123
Architecture 125
Digitized 125
Selectable 125
Common Access 125
Standardized Interface 125
Single Pipe 127
Goal 127
REVIEW 129
ISDN INTERFACES 133
Building Blocks 133
B, D Overview 133
B Channel 133
D Channel 133
ISDN Access 135
Access 135

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BASIC RATE INTERFACE 137
Capacity 137
Capability 137
BASIC RATE INTERFACE (BRI, 2B+D) 139
BRI, 2B+D 139
BRS - FACTORS AND BENEFITS 141
How It Works 141
Provisions 141
Capabilities 141
Benefits 141
REVIEW 143
PRIMARY RATE INTERFACE (23 B+D) 147
PRI (23B+D) 147
PRIMARY RATE INTERFACE (PRI, 23B+D) 149
PRI, 23B+D 149
How It Works 149
Benefits 149
FUTURE PRIMARY RATE INTERFACE CHANNELS 151
H0 and H11 Channels 151
H Channel Capabilities 151
H Channel Applications 151
ISDN USER/NETWORK INTERFACES 153
TE1 153
TE2 153
TA 153
NT1 153
NT2 153
LT 153
ET 153
REVIEW 155
DIGITAL SUBSCRIBER LINE - ANALOG IMPEDIMENTS 159
Analog Designed Network 159
Distance Limitations 159
Carrier Serving Area 159
Impediments 161
Cable Gauge 161
Bridge Taps 161
Load Coils 161

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BRI/PRI SPECIFICATIONS 163
BRI Criteria 163
PRI Criteria 163
REVIEW 165
CONCLUSION 167

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PART F: INTEGRATED SERVICES DIGITAL NETWORK

PURPOSE AND PREVIEW

Purpose

Special skills are required for the testing of Digital Subscriber Lines. The purpose of this section, the last in the module, is to introduce you to the Integrated Services Digital Network, or ISDN, and the concept of the Digital Subscriber Line (DSL). These two subjects go hand in hand: knowledge of ISDN is helpful in order to understand Digital Subscriber Lines. This section will introduce you to the basics, from theory to application of the concepts, so that you can appreciate the importance of the DSL.

Preview

Included in this section are these subjects:

- ☆ Factors leading to the development of ISDN
- ☆ ISDN concepts
- ☆ ISDN interfaces
- ☆ Basic Rate Interface (BRI)
- ☆ Primary Rate Interface (PRI)
- ☆ User and network interfaces
- ☆ Digital Subscriber Line
- ☆ Future loop developments

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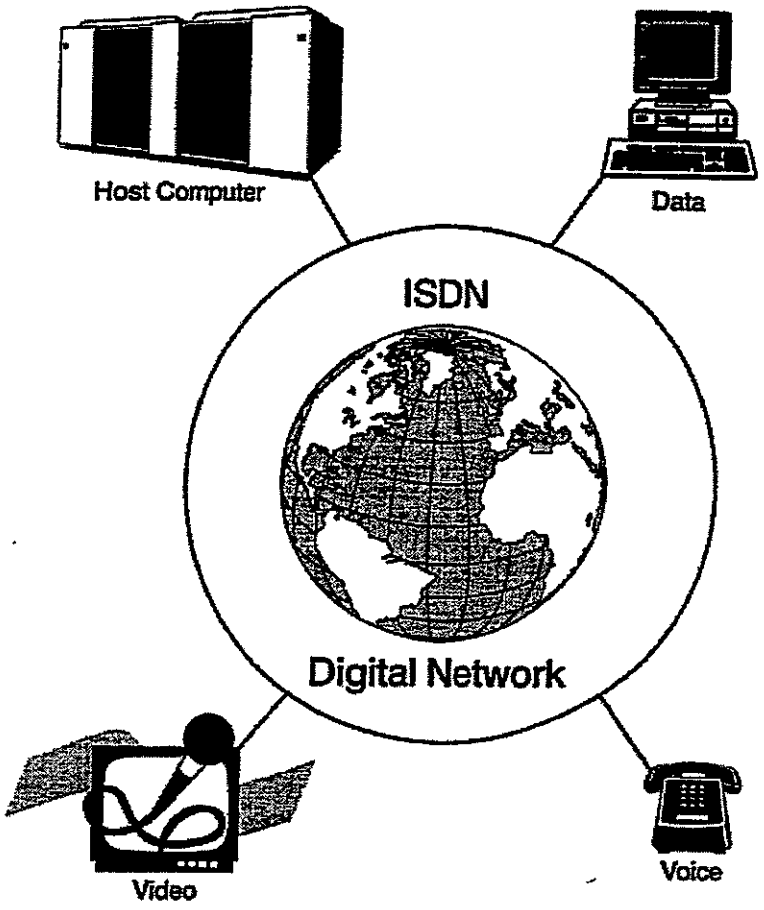
Integrated Services Digital Network



ISDN's advantages:

- ✔ An end-to-end digital network
- ✔ A single line serving voice and non-voice
- ✔ Standard user-to-network interfaces
- ✔ Intelligent signaling network

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INTRODUCTION

ISDN stands for Integrated Services Digital Network.

ISDN is a worldwide standard for access to an ever-expanding range of telecommunications services.

Advantages

Some of ISDN's advantages are as follows:

- ✔ [redacted] network - all-digital transmission will reduce the cost and provide cleaner and clearer telecommunications messages.
- ✔ A single line carrying voice and non-voice - access to different services will be over a single link, instead of requiring a different line for each service.
- ✔ Standard [redacted] network interfaces - ISDN calls for a standard set of standard customer network [redacted]es, facilitation equipment moves and changes.
- ✔ Intelligent signaling network - a range of new services and applications are made possible by ISDN's out-of-band signaling protocols.

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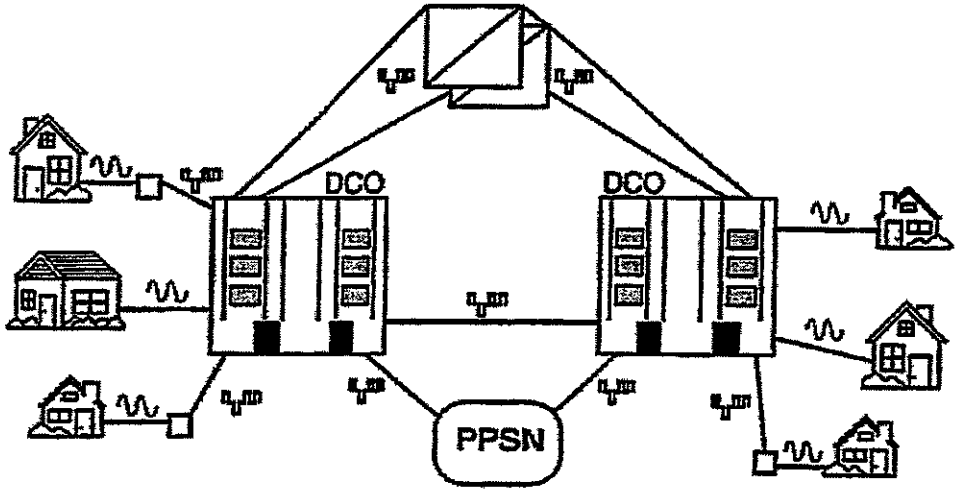
The Present



Key:
PPSN = Public Packet Switched Network
CCS/SS7 = Common Channel Signaling/Signaling System 7
DCO = Digital Central Office

= Digital Signal
= Analog Signal

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WHERE WE ARE TODAY

Let's take a brief snapshot of where the network is today, and where it will be with ISDN.

Today

- Digital Central Offices abound in metro areas, and rural digitization is a major on-going project in many areas, and is complete in some others. As shown in the top half of the illustration, the network still has analog components, notably the local subscriber loop.
- Packet Switching moves digital data on digital lines in a separate switched network. Packet switching is a shared digital data transport system that enables customers to share a transport circuit with others, saving the expense of a dedicated circuit.
- Common Channel Signaling/Signaling System 7 (CCS/SS7) is spreading rapidly to provide digital out-of-band signaling to the network. SS7, extended to customers' premises equipment, provides total end-to-end digital out-of-band signaling. Common Channel Signaling enables the voice network and the signaling network to become two separate systems. We will discuss CCS/SS7 later in the course.

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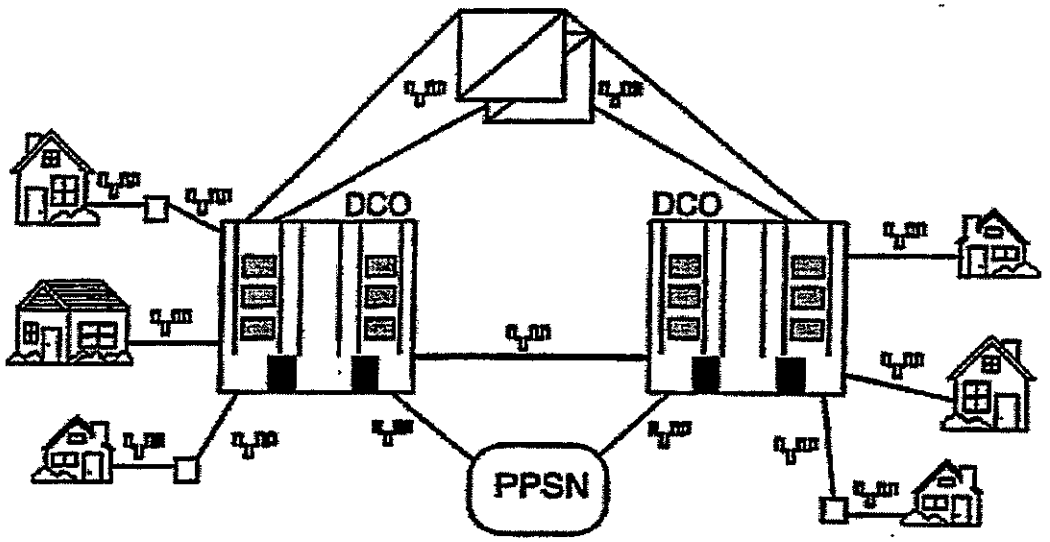
ISDN



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WHERE WE'LL BE TOMORROW

Tomorrow

- A Digital Subscriber Line (DSL) takes digital technology to the subscriber's premises, providing two separate phone lines on only one cable pair. By extending the digital out-of-band signaling to the DSL customer, we enter the world of ISDN. As shown in the lower part of the illustration, in essence, ISDN will digitize the local loop and provide total end-to-end digital capabilities.

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Integrated Services Digital Network (ISDN)

The name, "ISDN," arises from the concept that it will offer an integrated access to a myriad of voice and data services, using digital technology in a standard global network.

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INTEGRATED SERVICES DIGITAL NETWORK (ISDN)

Consumer Factors

Certain consumer factors are pushing the development of ISDN:

- Personal computers, fax machines, and other electronic devices are spreading from the workplace to the home.
- Subscribers want more information and services delivered to them:
  - ★ Shop at home networks
  - ★ Home banking, bill paying
  - ★ Energy management
  - ★ Security systems
  - ★ Telemarketing
  - ★ Video on demand
  - ★ Integrated voice and data on the same line

ISDN is the architecture of the network that will make this all possible.

ISDN Definition

Integrated Services Digital Network (ISDN) is an evolution of the modern network, extending digital network architecture over the local loop to the customer's premises. The name, "ISDN," arises from the concept that it will offer an integrated access to a myriad of voice and data services, using digital technology in a standard global network.

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ISDN Factors

Factors Leading to the International Standard:

- Frustrations with proprietary and non-compatible networks
- Increased international communications needs
- Digital's quality improvements
- Increased bandwidth needs
- Need for backward compatibility
- Multiple, simultaneous uses of a line
- Standard engineering specifications
- To help unlike data systems communicate

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ISDN - FACTORS

As the development of digital Central Office switches took place, it became apparent that a world-wide standard for extending the digital architecture for switched services to the customer's premises would be beneficial.

Standards

The benefits of a set of standard interfaces for networking are numerous. The Consultative Committee on International Telephony and Telegraphy (CCITT), under charter of the United Nations, became involved in developing such a set of standards. The emerging standards became known as ISDN.

Factors

Factors leading to the development of an international standard for telecommunications interfaces include:

- Frustrations in dealing with proprietary and non-compatible networks around the world.
- Increased international communications needs in a global market.
- Transmission quality improvements with digital architecture.
- Increases bandwidth needs.
- Need for backward compatibility with existing data and voice equipment.
- Multiple simultaneous uses for one communications line.
- Standard engineering specifications.
- Need to facilitate a standard to help unlike data services communicate effectively.

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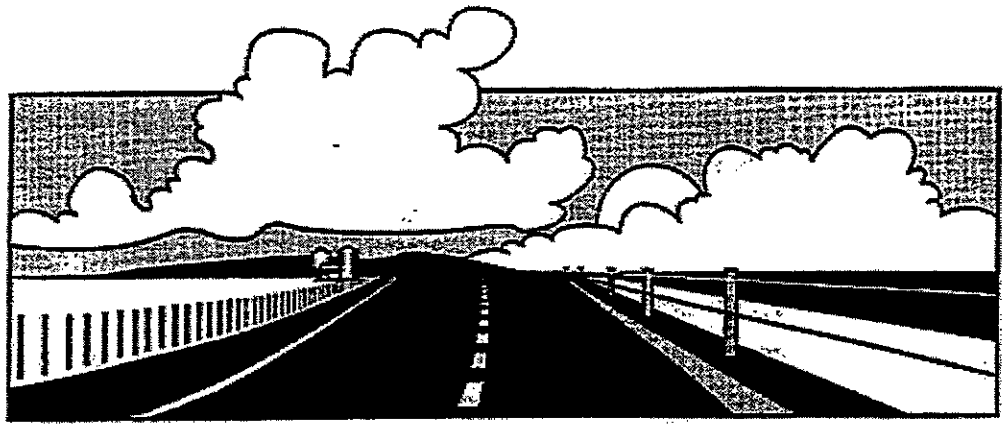

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REVIEW

1) An end-to-end digital network will reduce cost and will provide cleaner and clearer messages.

2) Standard user-to-network interfaces will facilitate equipment moves and changes.

3) Digital Subscriber Lines will provide two separate phone lines on one cable pair.

4) Certain consumer factors are limiting the development of ISDN. List two of these factors.
Voice/data on one line, security systems, etc.

5) The name, "ISDN," arises from the concept that it will offer an integrated access to a myriad of voice and data services, using digital technology in a standard global network.

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REVIEW - ANSWERS

1) An **end-to-end** digital network will reduce cost and will provide cleaner and clearer messages.

2) Standard user-to-network **interfaces** will facilitate equipment moves and changes.

3) Digital Subscriber Lines will provide **two** separate phone lines on **one** cable pair.

4) Certain consumer factors are pushing the development of ISDN. List two of these factors.
Any two of the following are acceptable: **personal computers, fax machines, or other electronic devices spreading to the home; shop at home networks; home banking/bill paying; energy management; security systems; telemetering; video on demand; integrated voice and data.**

5) The name, "ISDN," arises from the concept that it will offer an **integrated** access to a myriad of voice and data **services**, using **digital** technology in a standard global **network**.

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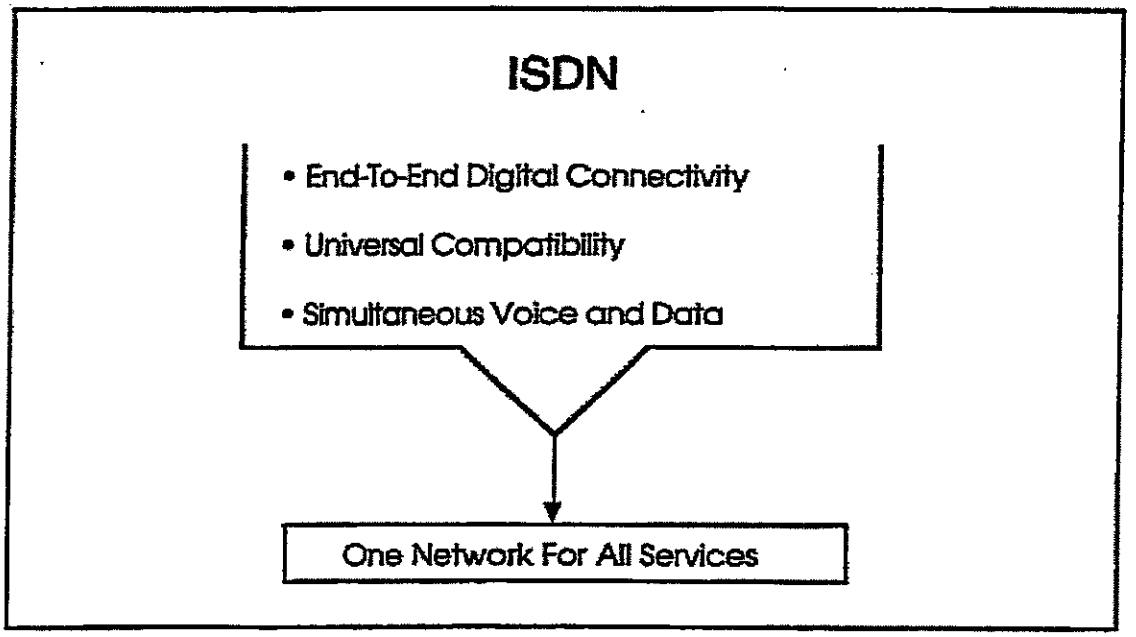
ISDN Concepts



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ISDN CONCEPTS

Telephone users, especially business customers, usually have separate networks for their voice, data and video because of the need to accommodate both analog and digital services.

Goal

It is expensive and inefficient to maintain and control these various networks. The goal of ISDN is a fully digital network where all of these services can share the same lines.

Phase-in

Obviously this change will not happen overnight. ISDN will be phased in over a number of years and will require a tremendous amount of money and resources. The concept of ISDN means end-to-end digital connectivity, without the presence of analog signals.

Compatibility

The concept also means the network will be universally compatible with all digital equipment, even the telephone instruments we use. ISDN will also make it possible to use a single line for both voice and data communications - simultaneously.

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ISDN Concepts

Major Concepts of ISDN

- Architecture, not a service
- Digitized
- Selectable
- Common access
- Standardized interface

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ISDN CONCEPTS, continued

The major concepts of ISDN are as follows:

Architecture — ISDN is an architecture, not a service. Services are transported by ISDN. ISDN is not about hardware or software, but rather, about the standards (or architecture) of the hardware and software.

Digitized — ISDN supports end-to-end digital connectivity - from the originating customer premises to the terminating customer premises.

Selectable — ISDN allows the customer to select desired network services on demand.

Common Access — ISDN provides a common access loop in a combination of copper or fiber digital carrier, depending on the facilities available and the ISDN interface selected.

Standardized Interface — ISDN provides a limited number of standard interfaces. Two interfaces have been defined: basic and primary rate. We'll discuss these shortly.

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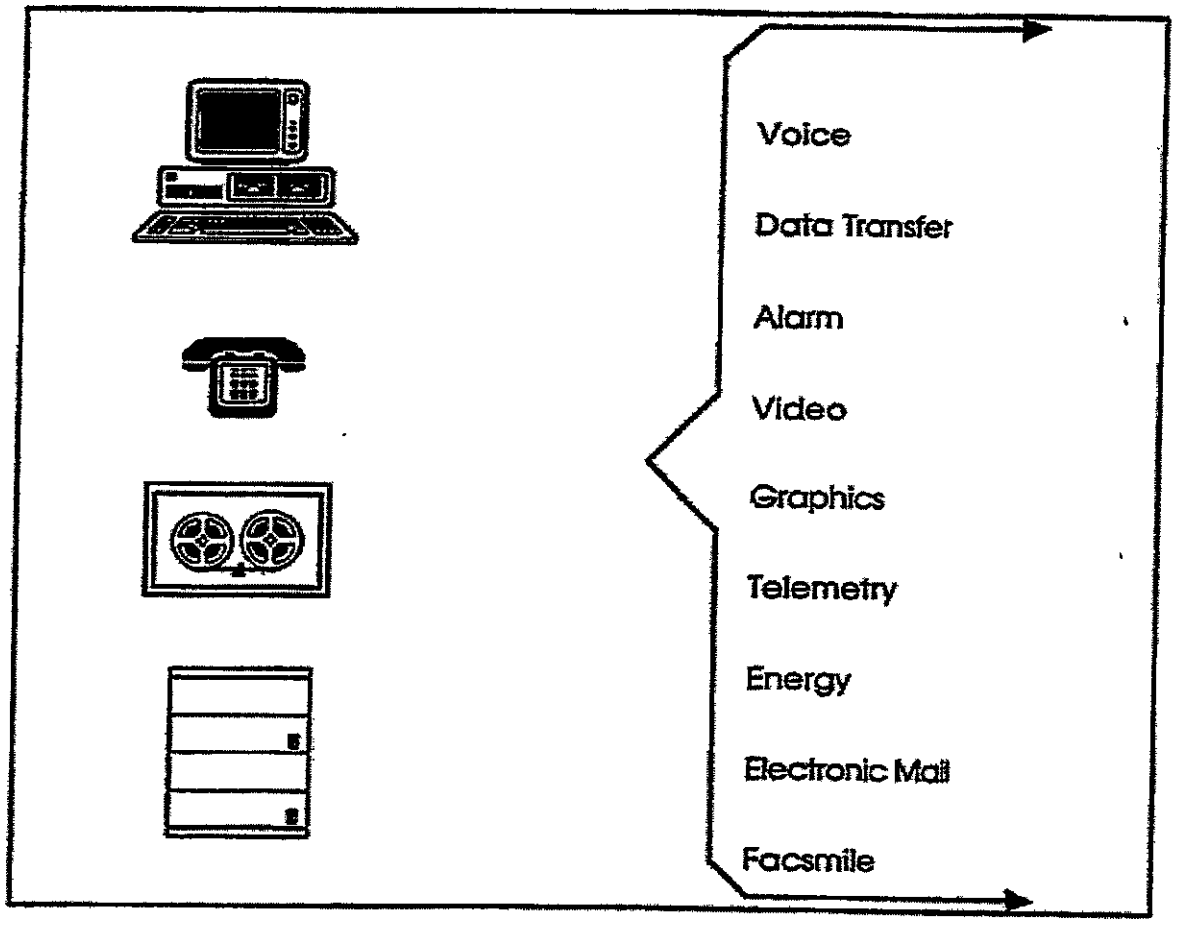
ISDN



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ISDN CONCEPTS, continued

Single Pipe

As shown in the illustration, with ISDN, one single "pipe" or network will be able to provide everything we have discussed, and more, whether it be voice, data, video, packet switching, graphics, energy management, electronic mail, videotex, or facsimile.

Goal

The goal of ISDN is to provide an internationally accepted standard for transmitting voice, data, video and signaling. And finally, by adding more bandwidth, a single line can handle a simultaneous voice conversation and data transmission.

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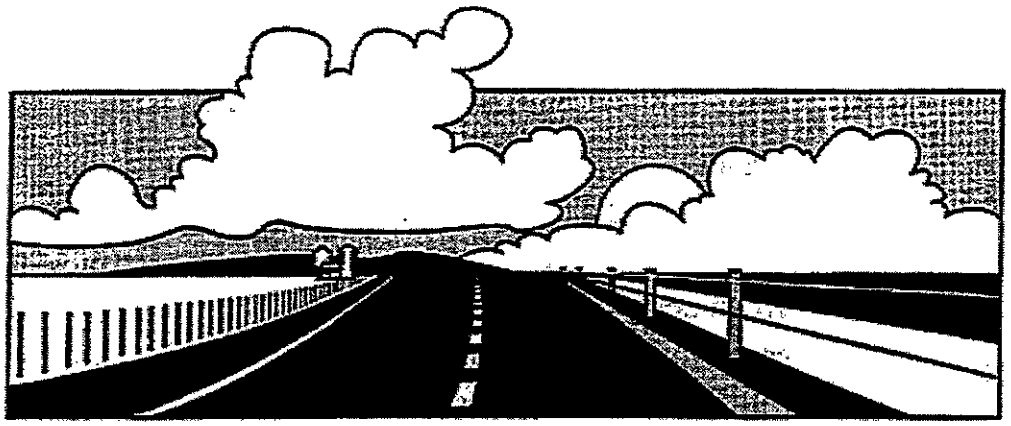

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REVIEW

1) The concept of ISDN means that the network will be universally Compatible with all digital equipment.

2) ISDN will make it possible to use a phone line for both voice and data communications - simultaneously.

3) ISDN is not about hardware or software, but rather, about the Standards of the hardware or software.

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REVIEW - ANSWERS

1) The concept of ISDN means that the network will be universally **compatible** with all digital equipment.

2) ISDN will make it possible to use a **single** line for both voice and data communications - simultaneously.

3) ISDN is not about hardware or software, but rather, about the **standards (or architecture)** of the hardware or software.

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ISDN Interfaces

- B and D channels are the building blocks for ISDN structure
- Channels:
  - "B" (Bearer) channel
    - Generic, all purpose carrier
    - Carries voice, data and video
    - 64 kbps transmission
  - "D" (Data) channel
    - Provides signaling
    - 16 kbps (BRI) 64 kbps (PRI)
    - Can provide low speed packet data
- BRI and PRI made up of "B" and "D" channels

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ISDN INTERFACES

Building Blocks

ISDN interfaces are defined in terms of their digital bit rate or "bandwidth." The basic building blocks of the ISDN line are the Bearer and Data channels, known as the B and D channels.

B, D Overview

The B channel carries user information, such as voice, data and video. It is called a Bearer channel because it is a generic, all-purpose carrier of 64 kbps of information. The D channel, or "data" channel, provides signaling and low speed packet data.

B Channel

The Bearer or "B" channel carries user information in the form of voice and non-voice digital information. It can be used for voice, data, FAX, graphics, or even low speed video. The Bearer channel has a bandwidth of 64 kbps.

D Channel

The Data or "D" channel is the customer's signaling channel, with a direct connection to the Central Office, and indirect connections to Signaling System 7. It provides signaling information for call set-up, clearing, etc. Depending on the application, the "D" channel may be either 64 kbps or 16 kbps. In some applications, low speed (9600 bits per second) packet switched data may be transmitted over the "D" channel.

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ISDN Access

- BRI and PRI made up of "B" and "D" channels

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ISDN ACCESS

Access

The CCITT currently defines the access to the customer (the standard channel interfaces) in two forms, the Basic Rate Interface (BRI) and the Primary Rate Interface (PRI). Both are made up of "B" and "D" channels.

Let's look at them in detail.

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Basic Rate Interface

B-Channel	64 kbps
B-Channel	64 kbps
D-Channel	16 kbps
Available to customer	144 kbps
MTNC & Control Channel	4 kbps
Framing	12 kbps
Total Basic Rate	160 kbps

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BASIC RATE INTERFACE

The Basic Rate Interface (BRI) is a standard that will convert the two-wire cable pair from the customer's home or office into a three-channel carrier system.

Capacity

The three channels are referred to as 2B+D. Two channels are 64 kbps B (Bearer) channels; one channel is a 16 kbps D (Data) channel. BRI gives the customer a capacity of 144 kbps for their communications needs. Maintenance and control adds 4 kbps and framing. Adds another 12 kbps. This gives us a total of 160 kbps over a single copper cable pair:

B-Channel	64 kbps
B-Channel	64 kbps
D-Channel	16 kbps
Available to customer	144 kbps
MTNC & Control Channel	4 kbps
Framing	12 kbps
Total Basic Rate	160 kbps

Capability

Basic Rate Service (BRS) provides integrated voice and data capability or data-only solutions. Separate channels can be used for different voice and/or data requirements simultaneously. For example, one B channel can be used for voice while a corresponding B channel on the same line can be transmitting data. This capability allows access to multiple communications services, such as text, image and video.

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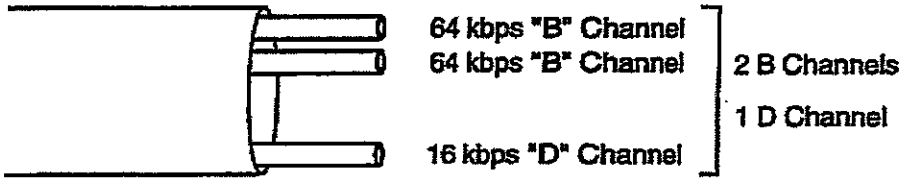
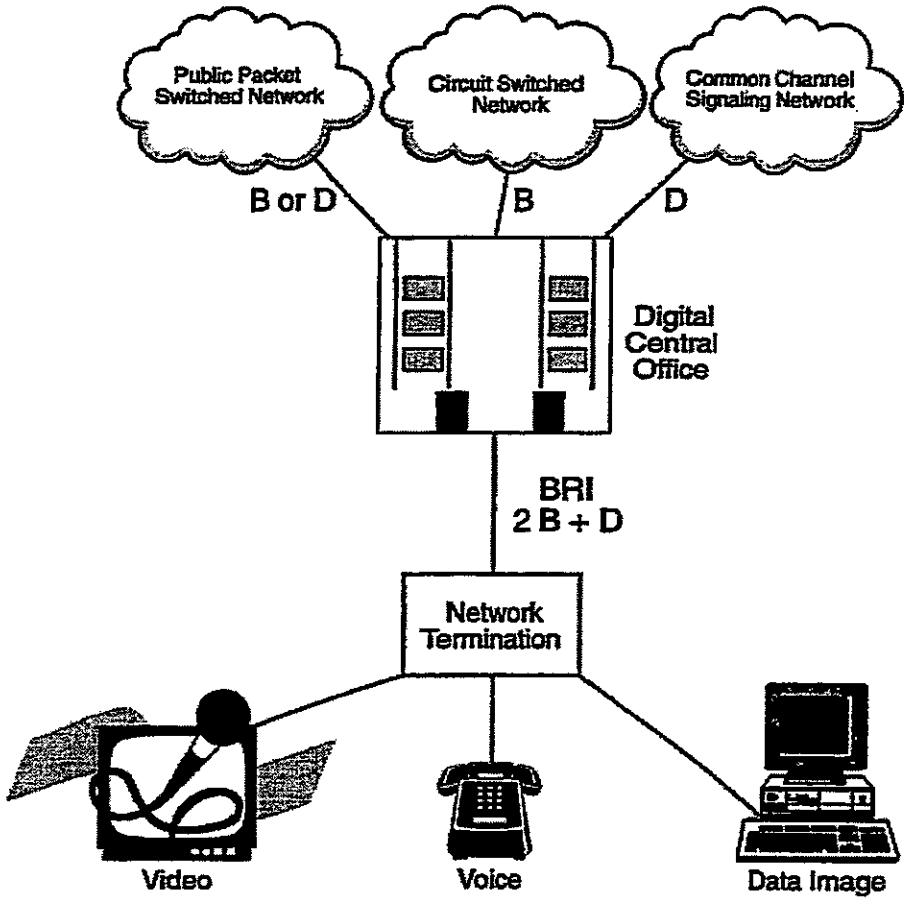
Basic Rate Interface (BRI)





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BASIC RATE INTERFACE (BRI, 2B+D)

BRI, 2B+D

The term, 2B+D, is used interchangeably with the term, Basic Rate Interface.

The following points are pertinent about 2B+D:

- It is intended for residential, small business or work station applications.

- Applications of the two 64 kbps Bearer channels include:
  - Voice
  - Telecommuting
  - High speed data transmission
  - Imaging - such as for medical, or real estate
  - Phase IV facsimile ("fax")
  - Compressed video
  - Integrated voice/data communications

- The 16 kbps data channel provides:
  - Digital, out-of-band signaling
  - 9600 bps packet switched data

- 2 B+D is designed for copper cable applications, utilizing two or four wire transmission. It terminates on a small multiplex unit.

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Basic Rate Service

Basic Rate Service:

- ❑ Consists of a Digital Subscriber Line on copper pairs
- ❑ Capabilities provided by a digital switch
- ❑ Benefits:
  - ✔ Flexibility and adaptability
  - ✔ End-to-end digital connectivity
  - ✔ Cost savings
  - ✔ Simultaneous voice and data capability

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BRS - FACTORS AND BENEFITS

How It Works

U S WEST provides the Basic Rate Service line that connects the customer to the network.

Provisions

BRS consists of a Digital Subscriber Line (DSL), provisioned on either a two-wire or a four-wire copper cable pair.

Capabilities

The Serving Central Office provides the voice, data and packet features. An ISDN compatible digital switch provides ISDN service.

Benefits

BRS benefits include:

- ✔ Flexibility and adaptability to varying customer needs.
- ✔ End-to-end digital connectivity for high-quality transmission.
- ✔ Cost savings resulting from faster transmission speeds and network sharing capabilities
- ✔ Simultaneous voice and data capability for access to multiple communications services, such as text, image and video.

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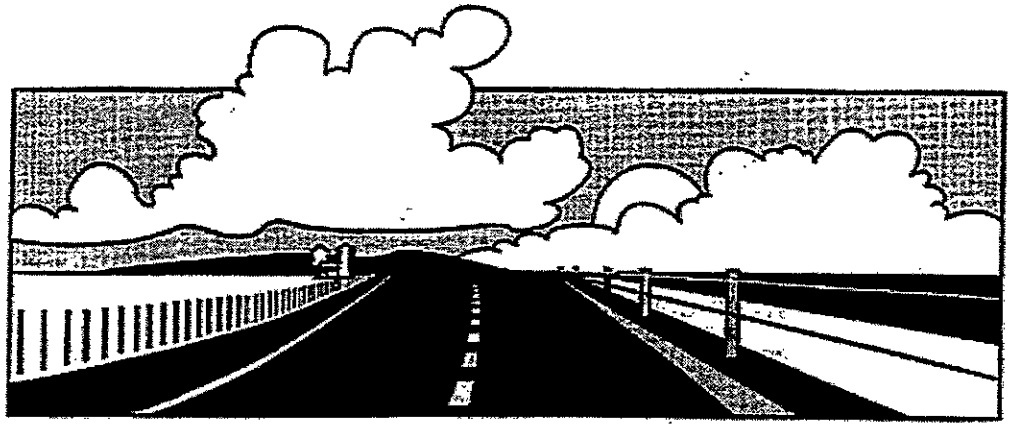

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REVIEW

1) Place a B (for Bearer channel) or a D (for Data channel) in the space provided.

D Carries signaling information
B Carries voice, [illegible] video
B All-purpose carrier
B 64 kbps bandwidth
D May carry low-[illegible]witched data

2) BRI, or Basic Rate Interface, is also known as 2B + D.

3) The Total Basic Rate for Basic Rate Interface is:

___ 1.544 Mbps
___ 16 kbps
✓ 160 kbps
___ 144 kbps

4) List one application that the two BRI Bearer channels can provide. Voice, data, [illegible]

5) Basic Rate Service consists of a Digital Subscriber Line, provisioned on either a two or four wire copper pair.

[illegible]L
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REVIEW - ANSWERS

1) Place a B (for Bearer channel) or a D (for Data channel) in the space provided.

D	Carries signaling information
B	Carries voice, data and video
B	All-purpose carrier
B	64 kbps bandwidth
D	May carry low-speed switched data

2) BRI, or Basic Rate Interface, is also known as **2 B+D**.

3) The Total Basic Rate for Basic Rate Interface is:

____	1.544 Mbps
____	16 kbps
X	160 kbps
____	144 kbps

4) List one application that the two BRI Bearer channels can provide. Any answer from the following list is acceptable: **Voice; telecommuting; data transmission; imaging; facsimile; compressed video; integrated voice/data.**

5) Basic Rate Service consists of a Digital **Subscriber** Line, provisioned on either a two or four wire copper pair.

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Primary Rate Interface

23 B-Channels (64 kbps x 23)	1.472 Mbps
1 D-Channel	64 kbps
Available to customer	1.536 Mbps
Framing	8 kbps
Total Primary Rate	1.544 Mbps

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PRIMARY RATE INTERFACE (23 B+D)

PRI (23B+D)

For larger applications, we can offer the Primary Rate Interface, or PRI. Referred to as 23 B+D, it provides 23 64 kbps B-Channels and one 64 kbps D-channel.

This service is based on the T1 specification of 1.544 Mbps and uses a repeated T1 Carrier line.

23 B-Channels (64 kbps x 23)	1.472 Mbps
1 D-Channel	64 kbps
Available to customer	1.536 Mbps
Framing	8 kbps
Total Primary Rate	1.544 Mbps

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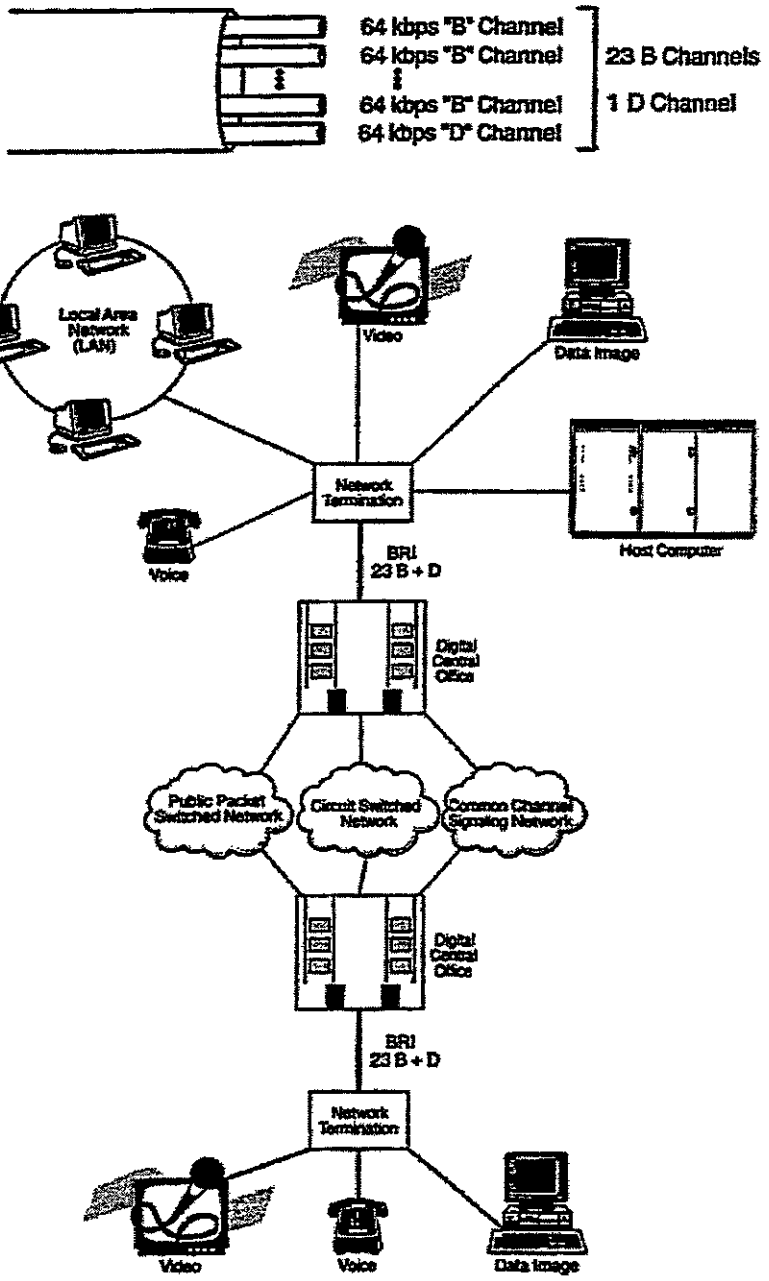
Primary Rate Interface



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PRIMARY RATE INTERFACE (PRI, 23B+D)

PRI, 23B+D

The following points apply to Primary Rate Interface (PRI, a.k.a. 23B+D):

- PRI is a four wire, regenerated span line system.
  - PRI operates at 1.544 Mbps transmission rate.
  - Distance is not a problem, as the line is regenerated.
- PRI is mainly designed for business applications.
- One 64 kbps data channel is used for signaling only.

How It Works

Customers connect to the Central Office over DS1 facilities operating at 1.544 Mbps. 23 DS0 channels are available for voice and data. The data or D channel is reserved for signaling over the CCS/SS7 network. 64 kbps is available to the user on each B channel.

A digital switch, such as an AT&T 5ESS or a Northern Telecom DMS-100 provides ISDN and PRS capabilities.

Benefits

The benefits of Primary Rate Interface include:

- A common digital network that facilitates worldwide communications.
- End-to-end digital connectivity for high quality transmission.
- Standard user interfaces that increase connectivity of user equipment.

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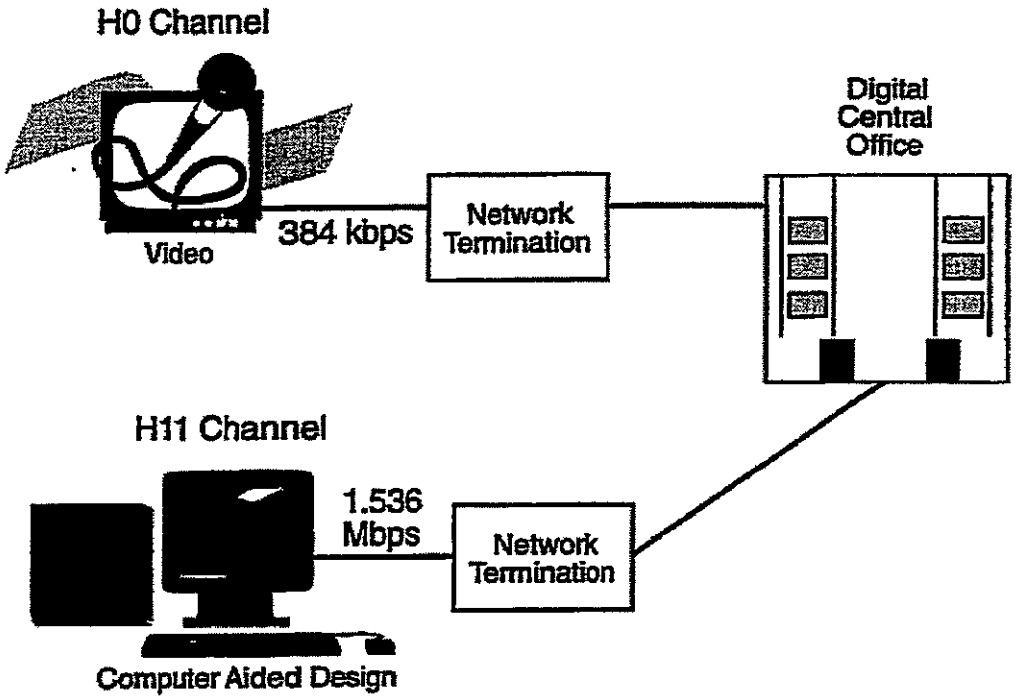
Future - H0 and H11



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FUTURE PRIMARY RATE INTERFACE CHANNELS

H11

Future Primary Rate Interface Channels that will become available are the H (for high speed) channels:

- ✔ The H0 channel, at 384 kbps bandwidth
- ✔ The H11 channel, at 1.536 Mbps bandwidth

H Channel Capabilities

The four-wire digital system to the user's premises can handle one Primary Rate Interface (23B+D), or:

- ☛ four H0 channels at 384 kbps each.
- ☛ one H11 channel at 1.536 Mbps.
- ☛ or, eventually, a combination of the above.

H Channel Applications

H channel applications could include video teleconferencing, Computer Aided Design (CAD), or large scale computer-to-computer file transfer. Eventually, the customer should be able to reconfigure their lines to any of these formats as their needs require.

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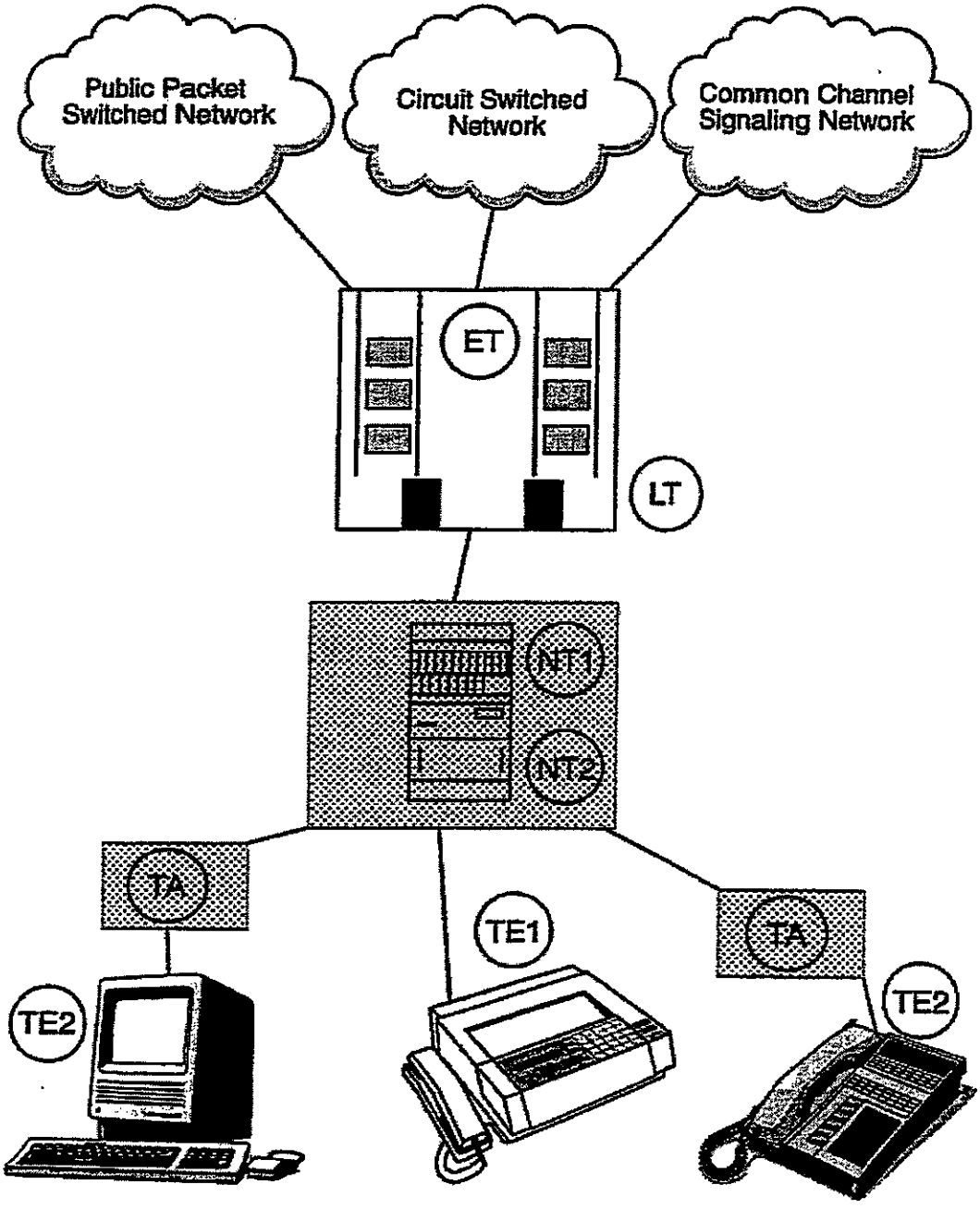
ISDN Interfaces



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ISDN USER/NETWORK INTERFACES

The following are the ISDN user and network interfaces, defined by the CCITT. Refer to the illustration on the opposite page as you read the following:

TE1 — Terminal Equipment 1: An ISDN-compatible terminal. The terminal is equipped with a standard ISDN physical interface.

TE2 — Terminal Equipment 2: A non-compatible terminal; equipped with a non-ISDN physical interface. ISDN does not support this type of terminal, which would require a terminal adapter (see TA).

TA — Terminal Adapter: An interface adapter to connect one or more TE2 devices to the network. Provides ISDN capabilities to equipment. Equivalent to a protocol or interface converter.

NT1 — Network Termination 1: A device responsible for the carrier's (e.g., telco) side of the conversion performing functions for; interface to ISDN equipment, conversion from two wire to four wire, maintenance of the loop electrical characteristics and access for remote testing.

NT2 — Network Termination 2: A possibly intelligent device responsible for the user's side of the connection to the network, performing such functions as multiplexing and switching (for example, a PBX). Depending on the customer's configuration, this device may not exist.

LT — Line Termination: The equivalent of NT1 at the telco's local exchange switch; NT1 and LT both terminate the local loop at their respective ends.

ET — Exchange Termination: The telco's local exchange switch.

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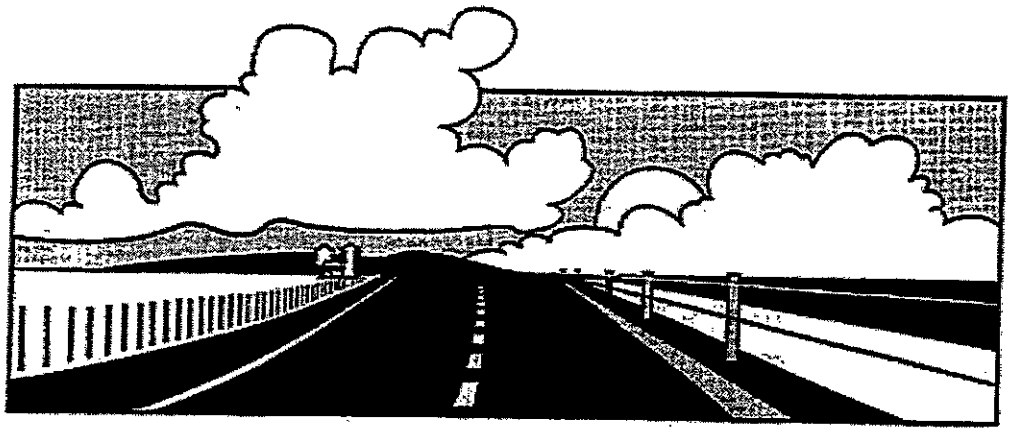

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REVIEW

1) PRI, or Primary Rate Interface, provides 23 64 kbps Bearer channels and 1 64 kbps Data channel.

2) With PRI, customers connect to the Central Office over T1 facilities operating at 1.544 Mbps.

3) List two benefits of Basic Rate Service.
~~Uses PRI~~ gives users Voice/Video
end-to-end digital connectivity

4) The CCITT has defined ISDN user and network interfaces. Label the following descriptions from the list below.

NT1
TA
TE1
ET
LT
TE2
NT2

TE2 A non-compatible terminal, equipped with a non-ISDN physical interface.

TA An interface adapter for non compatible terminals.

LT A device responsible for signal conversion, interfaces for ISDN equipment, maintenance and testing access, that operates on the telco side of the connection.

TE1 An ISDN compatible terminal.

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REVIEW - ANSWERS

1) PRI, or Primary Rate Interface, provides **23** 64 kbps Bearer channels and 1 64 kbps Data channel.

2) With PRI, customers connect to the Central Office over **DS1 (or T1)** facilities, operating at **1.544** Mbps.

3) List two benefits of Basic Rate Service. Any two of the Basic Rate Service benefits are acceptable answers: **Flexibility and adaptability; end-to-end digital connectivity; cost savings; simultaneous voice and data capability.**

4) The CCITT has defined ISDN user and network interfaces. Label the following descriptions from the list below.

NT1
TA
TE1
ET
LT
TE2
NT2

_TE2_ A non-compatible terminal, equipped with a non-ISDN physical interface.

_TA_ An interface adapter for non compatible terminals.

_NT1_ A device responsible for signal conversion, interface for ISDN equipment, maintenance and testing access, that operates on the telco side of the connection.

_TE1_ An ISDN-compatible terminal.

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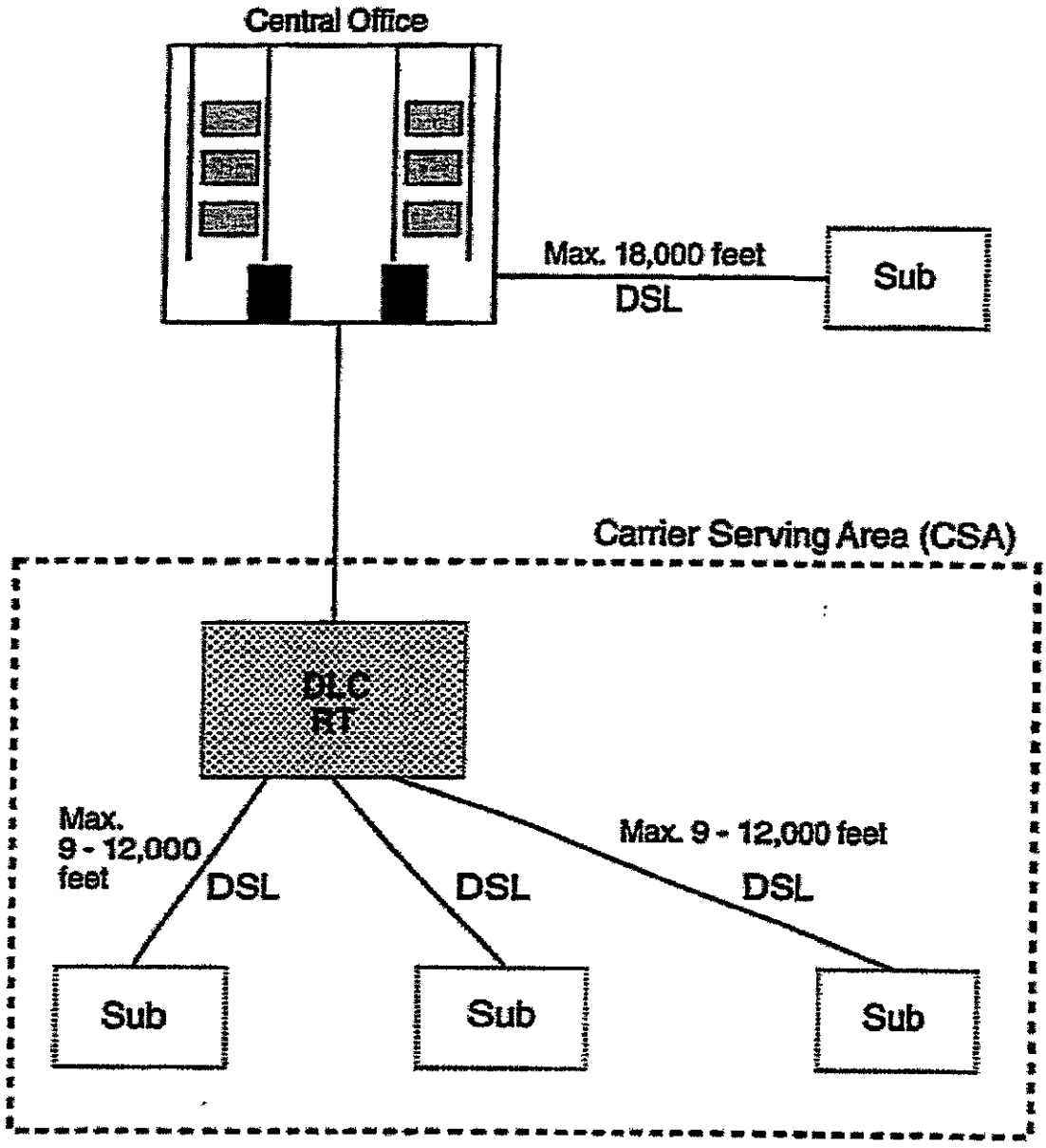
Digital Subscriber Line (DSL)
Carrier Serving Area (CSA)



Key:
DLC RT = Digital Loop Carrier Remote Terminal
Sub = Subscriber
DSL = Digital Suscriber Line

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DIGITAL SUBSCRIBER LINE - ANALOG IMPEDIMENTS

Analog Designed Network

As a result of the analog design of the network, there are impediments awaiting the digital signal. The outside plant was designed to carry up to 4 kHz of analog voice signal, and it does that well. Now we are asking it to carry 160 kbps of digital signal.

Distance Limitations

One impediment is distance. BRI was seen as a repeaterless type of service, with just a cable pair from the Central Office to the customer. However, technology today can only push the BRI digital signal about 18,000 feet on copper cable. While this distance is increasing gradually, steps need to be taken to deal with customers beyond the length limits.

Carrier Serving Area

To do this, the Carrier Serving Area (CSA) concept has been developed. This concept mixes standard cable pairs with Digital Loop Carrier (e.g., SLC-96 or DMS-1 Urban), as shown in the illustration.

The maximum cable length from the Digital Loop Carrier RT is 12,000 feet. If 26-gauge cable is used, the length from the Digital Loop Carrier RT is 9,000 feet.

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Analog Impediments

Analog impediments to the digital signal:

- ✘ Gauge changes
- ✘ Left-in bridge taps
- ✘ Load coils

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DSL - ANALOG IMPEDIMENTS - continued

Impediments

In addition to the factor of distance, outside plant contains these additional impediments to the BRI digital signal:

Cable Gauge

- ✘ Cables frequently change gauge (thickness). Most urban-type loops are 24 and 26 gauge cables, while a rural loops are 24 and 22 gauge. Since each cable gauge has its own impedance, the changing of gauges causes signal loss due to reflection. The loss is caused by the signal reflecting back to the transmitting end.

Bridge Taps

- ✘ Cables often have left-in bridge taps. Bridge taps are unused pairs of wires attached to a cable pair, used to serve previous customers. The customer disconnected, and now a spare branch runs off the cable pair. Bridge taps act as tributaries; they pick up noise, contribute to the capacitance of the wire and cause a reflection of the signal. Bridge taps severely attenuate high speed digital signals.

Load Coils

- ✘ Load coils are installed along cable to compensate for the capacitance effect in cable. Load coils add inductance to cable, reducing the overall frequency loss of the voice signal. Load coils, designed for analog signals, severely attenuate high-speed digital signals.

All of these problems are peculiar to the BRI digital signal. PRI is designed to transmit over a regenerated T1-Carrier line.

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DSL Limitations

DSL Limitations on Copper for BRI:

- No load coils
- Maximum of 2 bridge taps
- Maximum of two gauge changes per cable
- 18,000 maximum distance without DLC

DSL Limitations on Copper for PRI:

- No distance restrictions
- Same specifications as for a T1 span

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BRI/PRI SPECIFICATIONS

BRI Criteria

The following are the design criteria for the Basic Rate Interface Digital Subscriber Line:

- Non-loaded cables are required. There can be no load coils anywhere on the circuit.
- There can be a maximum of two bridge taps, not exceeding 2,500 ft in length; no one bridge tap longer than 2,000 ft.
- There can be a maximum of two gauge changes in the cable.
- 18,000 feet maximum distance on 26 gauge cable (this can be extended through the use of Digital Loop Carrier).

We can supply the Basic Rate Interface only to those customers that are located relatively close to the serving Central Office. Anyone further out will need to have their signal taken to their immediate area either by T-Carrier or by Subscriber Loop Carrier. As the technology increases, the distance that we can send this signal over copper wire will increase.

PRI Criteria

The digital subscriber loop for PRI is a 4-wire T-Carrier-like span with repeaters (regeneration). Since PRI is a regenerated signal, it does not have the distance restrictions of the BRI. Loop restrictions are the same as the carrier span restrictions PRI travels over.

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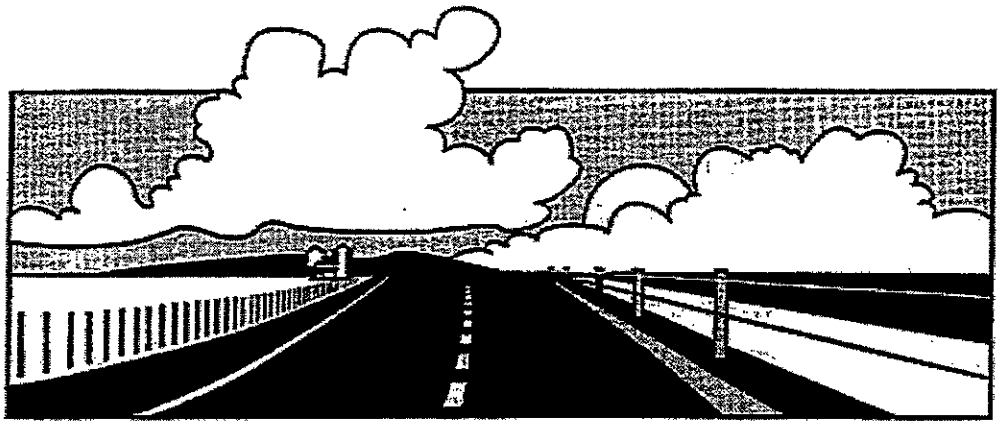

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REVIEW

1) For the Digital Subscriber Line the maximum length the signal can reach a subscriber is about 18K feet. Within a Carrier Serving Area, the distance from the Remote Terminal to subscribers is about 12K feet.

Match the following BRI digital signal impediments:

2) Load coils b

Left-in bridge taps c

Gauge changes a

a) Changes in cable thickness present impedance changes which cause signal loss due to reflection.

b) Installed along cables to add inductance, thereby reducing frequency loss. Affects high-speed digital signals.

c) Unused pairs of wires attached to a cable pair that act as tributaries, picking up noise and contributing to the resistance of the wire.

3) There can be a maximum of two gauge changes or bridge taps in copper cable carrying a Digital Subscriber Line.

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REVIEW - ANSWERS

1) For the Digital Subscriber Line, the maximum length the signal can reach a subscriber is about **18,000** feet. Within a Carrier Serving Area, the distance from the Remote Terminal to subscribers is about **9,000 to 12,000** feet.

2) Load coils **(b)**
Left-in bridge taps **(c)**
Gauge changes **(a)**

Either answer is acceptable.

3) There can be a maximum of two **gauge or left-in bridge taps** in copper cable carrying a Digital Subscriber Line.

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CONCLUSION

This concludes Module 1, Book III. Before taking the test, you may review the material in the Module. There is an index of subjects for Book III on the following pages. Clear up any questions you may have with the Instructor. Return to the beginning of Book III and review the objective. When you are ready, ask your Instructor for a copy of the test for Module 1, Book III.

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SUBJECT INDEX - BOOK III

Subject	Page
B or Bearer Channel	131
Basic Rate Interface (BRI)	
Applications	55
Capability	33
Capacity	65
Basic Rate Service	137
Carrier Serving Area	155
Chromatic dispersion	61
Cladding	39
Core	45
D or Data Channel	131
Digital Subscriber Line	
Analog impediments	157
Distance considerations	155
Specifications/limitations	159
Electromagnetic spectrum	23
Fiber optics	
Advantages	5
History	11
Introduction	3
Milestones	13
Physical make-up	45
Terms	33

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SUBJECT INDEX - BOOK III, continued

Subject	Page
Fiber optic cable	
Ribbon design cable	65
Splicing	69
Stranded design cable	67
Transmission loss	63
Types of fiber	47
Fiber optic system	
Components	75
Digital hierarchy	91
Equipment	89
Light transmitters	77
Optical regenerators	81
Protected facility	83
Regenerators	83
Repeater station	89
Unidirectional transmission	83
Future loop developments	103
ISDN	
Advantages	109
Concepts	123
Consumer factors	113
Definition	113
Factors	115
Standards	115
Where we are today/tomorrow	111
ISDN Interfaces	131
User/network interfaces	149
Laser	77
LED	77

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SUBJECT INDEX - BOOK III, continued

Subject	Page
Light receiver	
PIN	79
APD	79
Multimode Step Index fiber	49
Multimode Graded Index fiber	51
Packet switching	111
Primary Rate Interface	
Capacity	143
How it works	145
Future channels	147
Properties of light	15
Frequency	17
Propagation	17
Pulse/Modal dispersion	59
Refraction of light	25
Terms	33
Total internal reflection	37
Sheath	45
Single Mode Step Index fiber	53
2 B+D ..... see Basic Rate Interface	
23 B+D ..... see Primary Rate Interface	
U S WEST Fiber Optic Service	93
Features/applications	95
Dark/dim/Finished-Terminated fiber	101
Wavelength	17

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Introduction to Digital Technologies for COT

US*WEST*
COMMUNICATIONS

Module 2
Converting Numbering Systems

January, 2000

Table of Contents

CONVERTING NUMBERING SYSTEMS 1
PURPOSE AND PREVIEW 1
Objectives 2
OVERVIEW OF NUMBERING SYSTEMS 4
WEIGHTING 5
REVIEW 7
FROM DECIMAL 9
CONVERTING FROM DECIMAL TO BINARY 9
FROM DECIMAL TO BINARY - PRACTICE 13
CONVERTING FROM DECIMAL TO OCTAL 15
FROM DECIMAL TO OCTAL - PRACTICE 17
JOB AID 2A & 2B 19
JOB AID 2A & 2B - PRACTICE 21
CONVERTING FROM DECIMAL TO HEXADECIMAL 23
FROM DECIMAL TO HEXADECIMAL 24
FROM DECIMAL TO HEXADECIMAL 25
FROM DECIMAL TO HEXADECIMAL - PRACTICE 27
Reserved page for future use 29
FROM DECIMAL TO HEXADECIMAL - PRACTICE 32
FROM DECIMAL TO HEXADECIMAL - PRACTICE 34
JOB AIDS, 3, 4A, 4B 36
JOB AIDS 3, 4A, 4B - PRACTICE 38
TO DECIMAL 40
CONVERTING FROM BINARY TO DECIMAL 40
FROM BINARY TO DECIMAL - PRACTICE 42
FROM BINARY TO DECIMAL - PRACTICE 46
CONVERTING FROM OCTAL TO DECIMAL 48
FROM OCTAL TO DECIMAL - PRACTICE 50
FROM OCTAL TO DECIMAL - PRACTICE 54
CONVERTING FROM OCTAL TO DECIMAL USING JOB AID 2A ... 56
JOB AID 2A - PRACTICE 58
JOB AID 6A, 6B 60
CONVERTING FROM HEXADECIMAL TO DECIMAL 62
FROM HEXADECIMAL TO DECIMAL - PRACTICE 64
FROM HEXADECIMAL TO DECIMAL - PRACTICE 68

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FROM HEXADECIMAL TO DECIMAL - PRACTICE 72
FROM HEXADECIMAL TO DECIMAL - PRACTICE 76
JOB AIDS 3, 4A, 4B 78
JOB AIDS 3, 4A, 4B - PRACTICE 80
OPTIONAL DECIMAL TO HEXADECIMAL AND HEXADECIMAL TO DECIMAL - PRACTICE 82
TO BINARY 84
CONVERTING FROM OCTAL TO BINARY 84
FROM OCTAL TO BINARY - PRACTICE 86
FROM OCTAL TO BINARY - PRACTICE 90
CONVERTING FROM HEXADECIMAL TO BINARY 92
FROM HEXADECIMAL TO BINARY - PRACTICE 94
FROM HEXADECIMAL TO BINARY - PRACTICE 98
FROM BINARY 100
CONVERTING FROM BINARY TO OCTAL 100
FROM BINARY TO OCTAL - PRACTICE 102
FROM BINARY TO OCTAL - PRACTICE 106
CONVERTING FROM BINARY TO HEXADECIMAL 108
FROM BINARY TO HEXADECIMAL - PRACTICE 110
FIND BINARY TO HEXADECIMAL - PRACTICE 114
CONVERTING FROM OCTAL TO HEXADECIMAL 116
FIND OCTAL TO HEXADECIMAL - PRACTICE 118
FROM OCTAL TO HEXADECIMAL - PRACTICE 122
CONVERTING FROM HEXADECIMAL TO OCTAL 124
FROM HEXADECIMAL TO OCTAL - PRACTICE 126
FROM HEXADECIMAL TO OCTAL - PRACTICE 130
REVIEW 132
NUMBERING SYSTEMS CONVERSION CHART 136
CONCLUSION 137
SUBJECT INDEX - MODULE 2 138

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CONVERTING NUMBERING SYSTEMS

PURPOSE AND PREVIEW

Purpose

The purpose of the lesson is to enable you to identify and convert four different numbering systems. Familiarity with the four numbering systems is necessary to interpret Central Office printouts. Conversion of switch data from one numbering system to another is necessary to perform maintenance activities. You will be performing these numbering system conversions in your day-to-day work.

Preview

Subjects included in this module are as follows:

- ☆ Identifying the four numbering systems
- ☆ Weighting
- ☆ Converting from decimal to binary
- ☆ Converting from decimal to octal
- ☆ Converting from decimal to hexadecimal
- ☆ Converting from binary to decimal
- ☆ Converting from octal to decimal
- ☆ Converting from hexadecimal to decimal

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OBJECTIVES

At the conclusion of this module, the student will be able to:

- ❑ Correctly identify binary, octal, decimal, and hexadecimal numbering systems.
- ❑ Correctly convert decimal to binary and binary to decimal.
- ❑ Correctly convert decimal to octal and octal to decimal.
- ❑ Correctly convert decimal to hexadecimal and hexadecimal to decimal.

The student will be provided with a written test, comprised of completion type questions. During the test, the student may use the job aids but may not refer to this module.

Evidence of satisfactory learning will be demonstrated by correctly completing 15 out of 20 questions on the test.

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INTRODUCTION TO THE FOUR NUMBERING SYSTEMS

INTRODUCTION

The four numbering systems you will need to know for working with computers are decimal, binary, octal, and hexadecimal. This module covers all four.

Computers use binary numbers for internal operations such as addition and subtraction. However visual representations of these operations can be portrayed in hexadecimal and rarely in octal printouts.

Job aids explaining the procedural steps to convert octal and hexadecimal values into decimal and binary equivalents will be provided as handouts in this module.

This module will cover only the binary numbering system in detail as it relates to decimals. The handouts will be used to cross-reference all other numbering system values.

ABBREVIATIONS

The common abbreviations for the numbering systems covered in this module for example are:

Decimal	D.96
Binary	B.1110
Octal	O.54
Hexadecimal	X.27A

JOB AIDS

Locate numbering system Job Aids now and briefly familiarize yourself with them. You will be referring to the Job Aids throughout this module.

Note: If you have questions on any of the Job Aids, or if you are unsure how to use them, please see your Instructor.

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OVERVIEW OF NUMBERING SYSTEMS

DECIMAL

Webster's helps us with the definition of decimal: it is a numbering system numbered or proceeded by tens. The prefix in "dec" in Latin means 10. The decimal numbering system uses a base of 10.

BINARY

In Module 1 we told you that the binary system consists of two things or parts: 0 and 1. The binary numbering system uses a base of 2 (the two characters 0 and 1).

OCTAL

The octal numbering system uses a base of 8. The octal numbering system uses eight characters: 0 through 7.

HEXADECIMAL

The hexadecimal numbering system uses 16 characters: 0 through 9 and A through F. As the decimal system uses a base of 10, the hexadecimal uses a base of 16. (The prefix hex in Latin means 6, and you know that dec means 10. Add the two numbers and you have 16.)

Hexa (6) + decimal (10) = Hexadecimal (16)

X.0 = D.0	X.4 = D.4	X.8 = D.8	X.C = D.12
X.1 = D.1	X.5 = D.5	X.9 = D.9	X.D = D.13
X.2 = D.2	X.6 = D.6	X.A = D.10	X.E = D.14
X.3 = D.3	X.7 = D.7	X.B = D.11	X.F = D.15

JOB AID 1

Job Aid 1 shows the decimal, binary, octal, and hexadecimal equivalents from D.0 through D.49. You will want to refer to it throughout this module.

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WEIGHTING

Each column in a numbering system has a fixed decimal weight which is determined by powers of the base system.

DECIMAL

In decimal, column 1 (rightmost) is weighted at 10^0, which is 1. (Any number to the power of 0 equals 1.) Column 2 is weighted at 10^1, which is 10. (Any number to the power of 1 equals itself.) Column 3 is weighted at 10^2, which is 100 ($10^2 = 10x10$). Column 4 is weighted at 10^3, which is 1000 ($10^3 = 10x10x10$). The chart below shows the weights of the first four columns in decimal.

Column	4	3	2	1
Power of 10	10^3	10^2	10^1	10^0
Weight	1000	100	10	1

BINARY

In binary, the columns are weighted by powers of 2. Column 1 is 2^0, which is 1. Column 2 is 2^1, which is 2. Column 3 is 2^2, which is 4 ($2^2 = 2x2$). Column 4 is 2^3, which is 8 ($2^3 = 2x2x2$). Here are the weights of the first four columns.

Column	4	3	2	1
Power of 2	2^3	2^2	2^1	2^0
Weight	8	4	2	1

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WEIGHTING, CONTINUED

OCTAL

In octal, the columns are weighted by powers of 8. Column 1 is 8^0, which is 1. Column 2 is 8^1, which is 8. Column 3 is 8^2, which is 64 ($8^2 = 8x8$). Column 4 is 8^3, which is 512 ($8^3 = 8x8x8$).

Column	4	3	2	1
Power of 8	8^3	8^2	8^1	8^0
Weight	512	64	8	1

HEXADECIMAL

In hexadecimal, each column from right to left is weighted at 16 times the decimal value of the column to its right. Here are the first four columns.

Column	4	3	2	1
Power of 16	16^3	16^2	16^1	16^0
Weight	4096	256	16	1

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REVIEW

Answer the questions in the spaces provided.

a) Indicate in the blanks the base of each of the following number systems.

1. 10 Decimal
2. 2 Binary
3. 8 Octal

364 8 / 512

b) In the decimal system, the decimal weight of column 2 is $10^1 = 10$.

c) In the octal system, the decimal weight of column 4 is _____. $8^3 = 512$

d) In the binary system, the decimal weight of column 2 is $2^1 = 2$.

e) The hexadecimal numbering system uses 16 (how many) characters.
0 through 15
A through F

f) In hexadecimal:

1) The column weights are based on powers of 16.

2) The weight in column 3 is $16^2 = 256$.

3) The weight in column 4 is $16^3 = 4096$.

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REVIEW - ANSWERS

a) 1. 10
2. 2
3. 8

b) 10

c) 512

d) 2

e) 16
0 through 9
A through F

f) 1) 16

2) 256

3) 4096

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FROM DECIMAL

CONVERTING FROM DECIMAL TO BINARY

The basic mathematical function used in converting decimal to binary is division. Remember, when you start with decimal, you divide. Follow the four steps in the example on the next page to convert decimal to binary.

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FROM DECIMAL TO BINARY, continued

Example D.25 = B. _____

(1) Divide the decimal number by the system's base (for binary, use 2).

```
 12          (quotient)
2/ 25
 2
 05
  4
  1          (remainder)
```

(2) Record the remainder in the first (rightmost) column of the answer.

B. 1

First column

(3) Divide the quotient of your previous division problem by the system's base (2 in our example).

```
  6
2/ 12
 12
  0
```

(4) Record the remainder in the Next column of the answer

B. 01

Repeat steps 3 and 4 until the quotient is 0.

(3) (Repeated.)

```
  3
2/ 6
  6
  0
```

(4) (Repeated.) B. 001

(Example continued on the following page.)

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FROM DECIMAL TO BINARY, continued

Example cont'd (3) (Repeated.)

```
  1
2/3
 2
 1
```

(4) (Repeated.) B. 1001

(3) (Repeated.)

```
  0
2/1
 0
 1
```

(4) (Repeated.) B. 11001

Answer: D.25 = B.11001

Remember, the dividing is finished when the quotient is 0.

Notice that in binary the remainder is always 1 or 0, since there are only two characters in binary.

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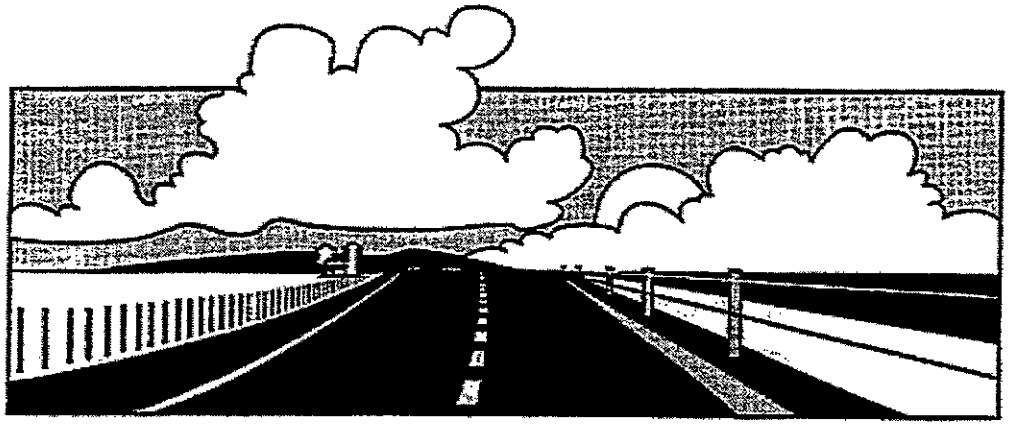

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FROM DECIMAL TO BINARY - PRACTICE

Find the binary equivalents for the decimal numbers below.

a) D.15 = B. 1111

b) D.570 = B. 1000111010

c) D.87 = B. _____

d) D.30 = B. _____

1110
8421

100|1010.

FROM DECIMAL TO BINARY - PRACTICE ANSWERS

a) B.111

(1) Divide.

```
   7
2/ 15
  14
   1
```

(2) Record. B. 1

(3) Divide quotient.

```
   3
2/ 7
  6
  1
```

(4) Record. B. 11

(3) (Repeated.)

```
   1
2/ 3
  2
  1
```

(4) (Repeated.) B. 111

(3) (Repeated.)

```
   0
2/ 1
  0
  1
```

(4) (Repeated.) B. 1111

Answer: D.15 = B.1111

b) B.1000111010
c) B.1010111
d) B.11110

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CONVERTING FROM DECIMAL TO OCTAL

Steps

Refer to handout Job Aids to cross-reference decimal to octal.

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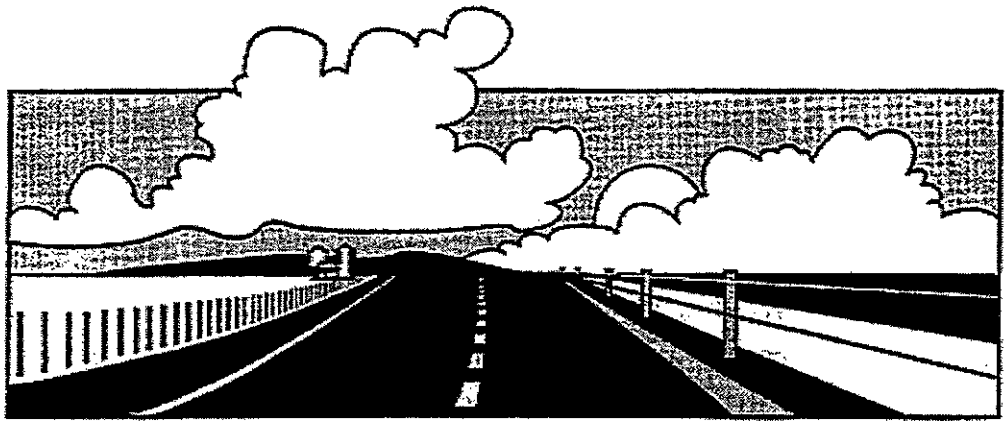

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FROM DECIMAL TO OCTAL - REVERSE

Using Job Aid Find the octal equivalents for the decimal numbers below.

a) D.765 = O. _____

b) D.516 = O. _____

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FROM DECIMAL TO OCTAL - PRACTICE ANSWERS

a) O.1375
b) O.1004

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JOB AID 2A & 2B

CONVERTING FROM DECIMAL TO OCTAL

Job Aid 2A and Job Aid 2B consist of conversion charts that provide for decimal-to-octal and octal-to-decimal conversion. Job Aid 2A covers numbers through D.383. Job Aid 2B covers numbers through D.767. Let's use Job Aid 2A to convert from decimal to octal. In our example we will use the numbers in boxes. Follow the four steps below.

Example D.172 = O.

(1)	Find the decimal number you want to convert	0172
(2)	Find the octal number in the far left column on the same line.	0250
(3)	Find the octal character at the top of the column that contains the decimal number.	4
(4)	Substitute the character from step 3 for the 0 in the rightmost position of the number from step 2. (Drop the first digit if it is 0.)	254

Answer: D.172 = O.254

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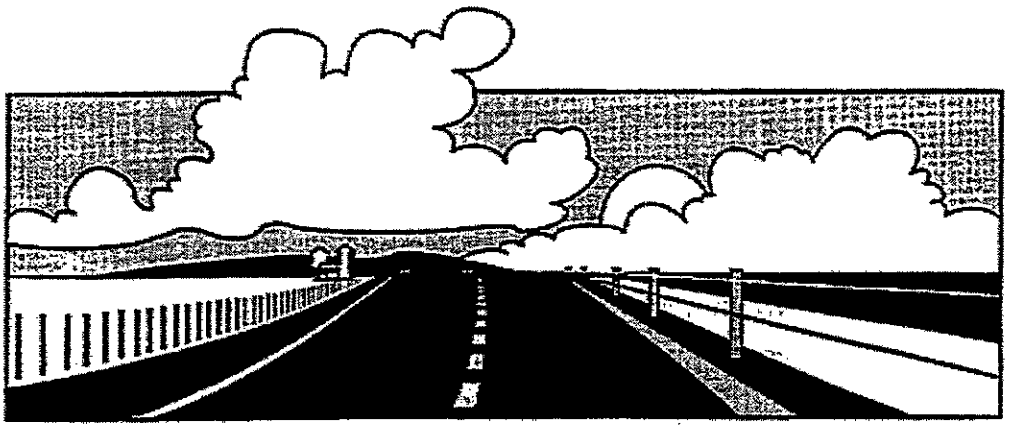

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JOB AID 2A & 2B - PRACTICE

Using Job Aid 2A and 2B, convert the decimal numbers below to octal.

a) D.234 = O. _____

b) D.450 = O. _____

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JOB AID 2A & 2B - PRACTICE ANSWERS

a) O.352

b) O.702

If your answers were correct, continue on to the next page. If not, ask your instructor for assistance.

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CONVERTING FROM DECIMAL TO HEXADECIMAL

Steps

Refer to handout Job Aids to cross-reference decimal to hexadecimal

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FROM DECIMAL TO HEXADECIMAL

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16
2 (remainder)

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FROM DECIMAL TO HEXADECIMAL

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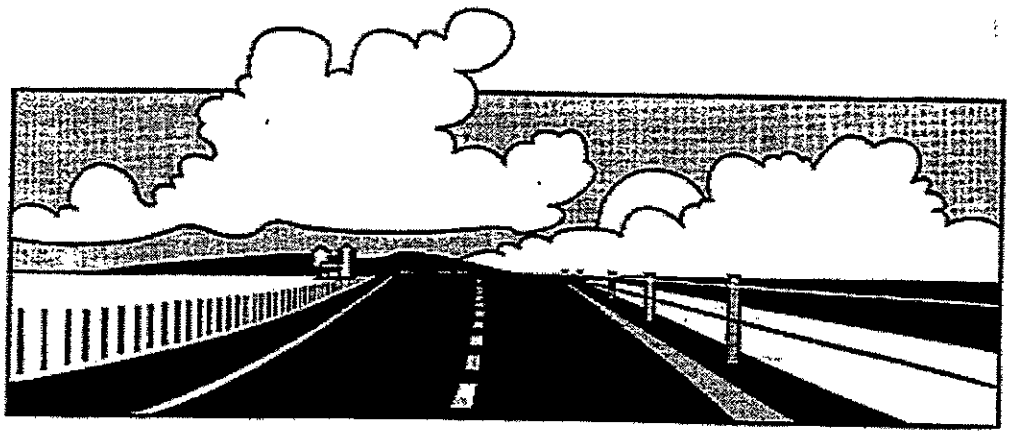

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FROM DECIMAL TO HEXADECIMAL - PRACTICE

Find the hexadecimal equivalents for the decimal numbers below from Job Aids.

a) D.525 = X. _____

b) D.1027 = X. _____

c) D.25 = X. _____

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FROM DECIMAL TO HEXADECIMAL - PRACTICE ANSWERS

a) X.20D

b) X.403

c) X.19

If your answers were correct, go to page 33. If not, continue onto the next page.

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FROM DECIMAL TO HEXADECIMAL, continued

Example D.1983=X.----------

Answer: D.1983 = X.7BF

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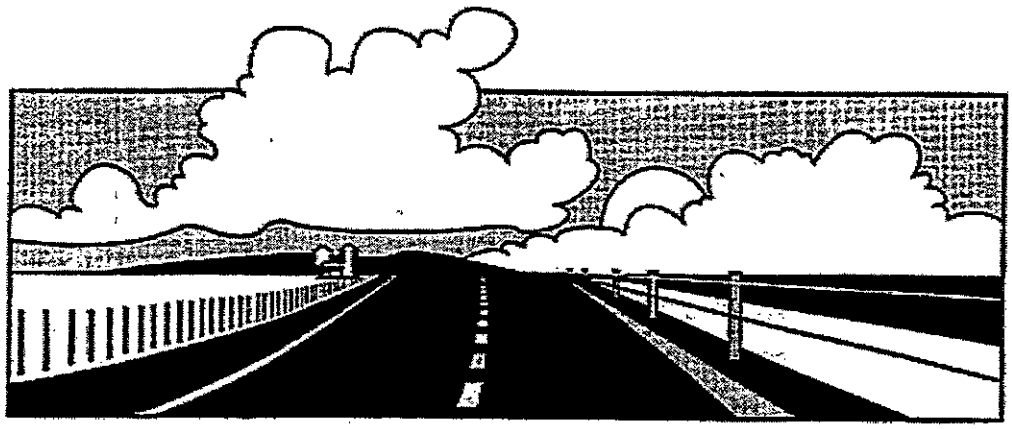

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FROM DECIMAL TO HEXADECIMAL - PRACTICE

Find the hexadecimal equivalents for the decimal numbers below for additional practice.

a) D.1776 = X. _____

b) D.42 = X. _____

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FROM DECIMAL TO HEXADECIMAL - PRACTICE ANSWERS

Answer:

a) X.6F0

b) X.2A

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FROM DECIMAL TO HEXADECIMAL - PRACTICE

Work the conversion problems below.

a) D.94 = X. _____

b) D.3101 = X. _____

c) D.127 = X. _____

d) D.358 = X. _____

e) D.2867 = X. _____

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FROM DECIMAL TO HEXADECIMAL - PRACTICE ANSWERS

a) X.5E

b) X.C1D

c) X.7F

d) X.166

e) X.B33

If your answers were correct, go on to the next page. If not, ask your instructor for assistance on anything you did not understand.

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JOB AIDS, 3, 4A, 4B

Job Aids 3, 4A, 4B

Job Aid 3 covers numbers up to D.767 (Job Aid 4A and 4B cover higher numbers). These job aids can help you convert more easily and accurately.

Follow the four steps below to convert from decimal to hexadecimal. Follow along on Job Aid 3. We will use the numbers in boxes. For our example, we will use D.399.

Example

D.399 = X. _____

(1)	Find the decimal number you want to convert.	0399
(2)	Find the hexadecimal number The far left column on the Same line.	0180
(3)	Find the hexadecimal Character at the top of the Column that contains the Decimal number	F
(4)	Substitute the character from Step 3 for the 0 in the Rightmost position of the Number from step 2. Drop the Beginning 0.	18F

Answer: D.399 = X.18F

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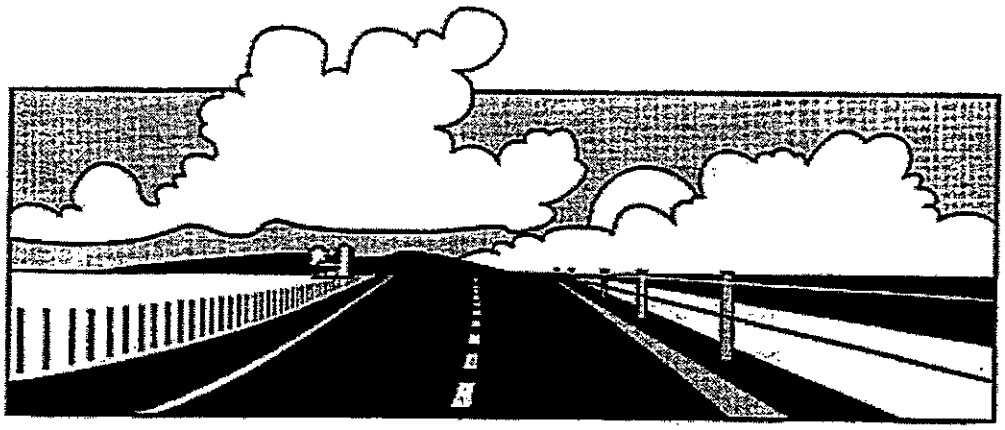

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JOB AIDS 3, 4A, 4B - PRACTICE

Job Aid 4A and Job Aid 4B contain directions for converting decimal to hexadecimal and vice versa. Study the examples and then use Job Aids 3, 4A and 4B to answer the questions below.

Use Job Aids 3, 4A and 4B to work the problems below.

a) D.595 = X. _____

b) D.752 = X. _____

c) D.1207 = X. _____

d) D.3101 = X. _____

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JOB AIDS 3, 4A, 4B - PRACTICE ANSWERS

a) X.253

b) X.2F0

c) X.4B7

d) X.C1D

If your answers were correct, go on to the next page. If not, ask your instructor for assistance on anything you did not understand.

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TO DECIMAL

CONVERTING FROM BINARY TO DECIMAL

Steps

To convert from binary or octal to decimal, follow the three steps below.

(1) Determine the decimal weight of each digit of the number.

(2) Multiply the decimal weight of each column by the digit in that column

(3) Add the products of step 2.

Example

In this example, B.1101 is converted to decimal:

(1) Weight.

Weight	8	4	2	1
Binary No.	1	1	0	1

(2) Multiply.

1 x 1 = 1
0 x 2 = 0
1 x 4 = 4
1 x 8 = 8

(3) Add. 13

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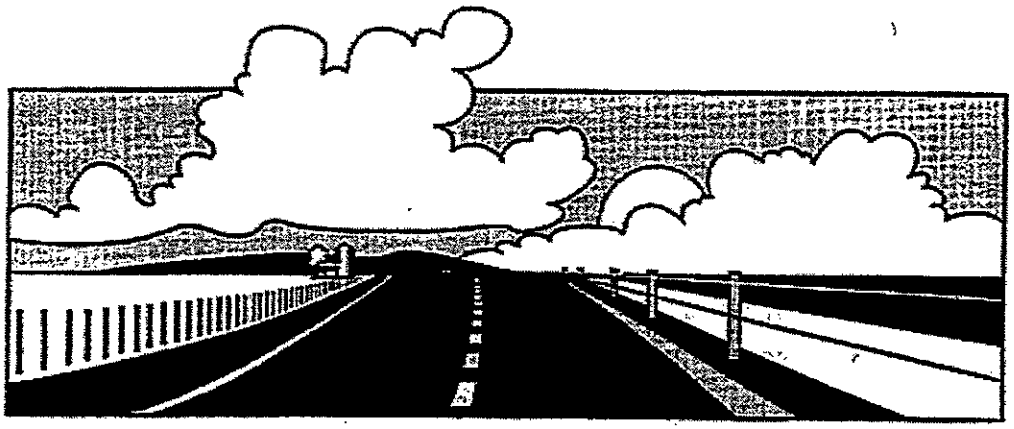

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FROM BINARY TO DECIMAL - PRACTICE

Find the decimal equivalents for the binary numbers below.

a) B.1110 = D. _____

b) B.0110 = D. _____

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FROM BINARY TO DECIMAL - PRACTICE ANSWERS

a) D.14

(1) Weight.

Weight	8	4	2	1
Binary No.	1	1	1	0

(2) Multiply.

0 x 1 = 0
1 x 2 = 2
1 x 4 = 4
1 x 8 = 8

(3) Add. 14

Answer: B.1110 = D.14

b) D.6

FROM BINARY TO DECIMAL, continued

Example

Here is an example with more than four columns:

B.11001010 = D. _____

(1) Weight.

Weight	128	64	32	16	8	4	2	1
Binary No.	1	1	0	0	1	0	1	0

(2) Multiply. (Since 0 times any number is 0 and 1 times any number is the number, you can skip this step in binary.)

(3) Add. (Add all weights that have 1 under them.)

2
8
64
128
202

Answer: B.11001010=D.202

Job Aid 5

Refer to Job Aid 5 for an example of conversion by weighting.

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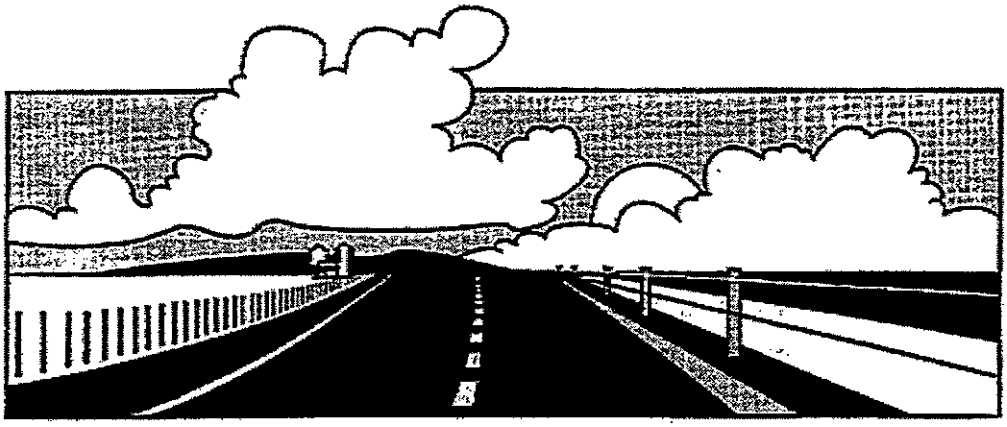

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FROM BINARY TO DECIMAL - PRACTICE

Find the decimal equivalents for the binary numbers below.

a) B.10101010 = D. _____

b) B.1111001 = D. _____

c) B.0010101111* = D. _____

* The binary number is the same with or without the beginning 0's.

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FROM BINARY TO DECIMAL - PRACTICE ANSWERS

a) D.170

(1) Weight.

Weight	128	64	32	16	8	4	2	1
Binary No.	1	0	1	0	1	0	1	0

(2) Multiply. (skip to binary.)

(3) Add. (add all weights that have 1's under them.)

2
8
32
128
170

Answer: B.10101010 = D.170

b) D.121

c) D.175

If your answers were correct, continue on the next page; if not, see your instructor for assistance.

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CONVERTING FROM OCTAL TO DECIMAL

Steps

Converting from octal to decimal uses the same three steps as converting from binary to decimal. Only the weights of the columns are different. Remember the steps: weight, multiply, add.

In the example below, note that we are using powers of 8 to determine the decimal weight of each column.

Example

O.5712 = D. _____

(1) Weight.

Weight	512	64	8	1
Octal No.	5	7	1	2

(2) Multiply.

2 x 1 =	2
1 x 8 =	8
7 x 64 =	448
5 x 512 =	2560

(3) Add. 3018

Answer: O.5712 = D.3018

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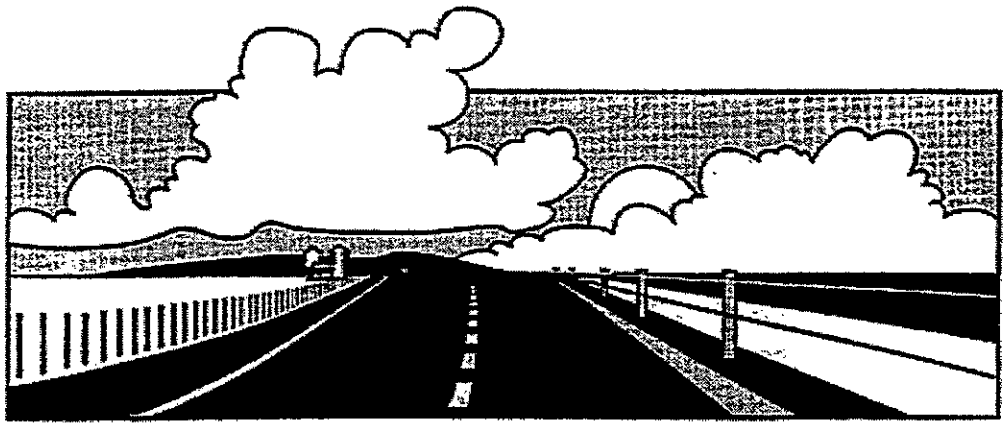

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FROM OCTAL TO DECIMAL - PRACTICE

Find the decimal equivalents for the octal numbers below.

a) O.5601 = D. _____

b) O.125 = D. _____

c) O.7761 = D. _____

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FROM OCTAL TO DECIMAL - PRACTICE ANSWERS

a) D.2945

(1) Weight.	Weight	512	64	8	1
	Octal No.	5	6	0	1

(2) Multiply.	1 x 1 = 1
	0 x 8 = 0
	6 x 64 = 384
	5 x 512 = 2560
(3) Add.	2945

Answer: O.5601 = D.2945

b) D.85

c) D.4081

If your answers were correct, go on to page 55. If not, continue on the next page.

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FROM OCTAL TO DECIMAL, continue

Example

Study the example below. Remember the three steps: weight, multiply, add. We used powers of 8 to determine the decimal weight of each column of the octal number.

O.165 = D. _____

(1) Weight.	Weight	64	8	1
	Octal No.	1	6	5
(2) Multiply.			5 x 1 =	5
			6 x 8 =	48
			1 x 64 =	64
(3) Add.				117

Answer: O.165 = D.117

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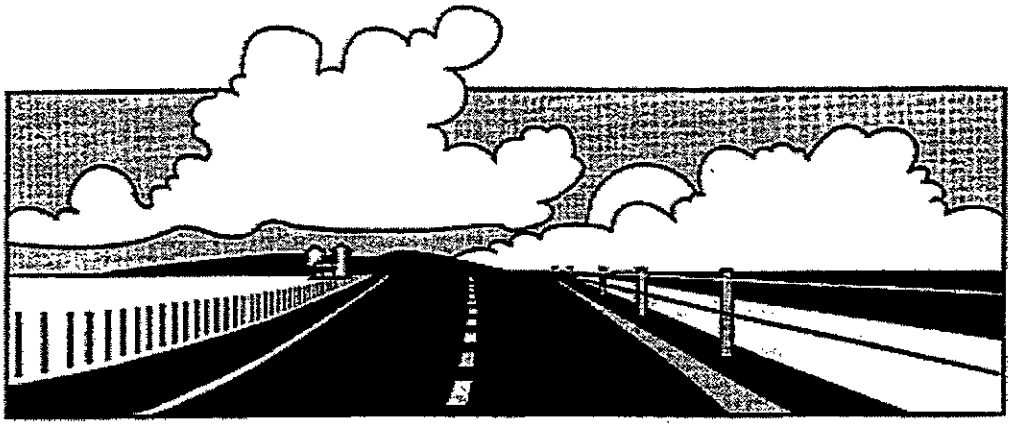

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FROM OCTAL TO DECIMAL - PRACTICE

Find the decimal equivalents for the octal numbers below.

a) O.111 = D. _____

b) O.777 = D. _____

c) O.27 = D. _____

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FROM OCTAL TO DECIMAL - PRACTICE ANSWERS

a) D.73

(1) Weight.

Weight	64	8	1
Octal No.	1	1	1

(2) Multiply.

1 x 1 = 1
1 x 8 = 8
1 x 64 = 64

(3) Add. 73

Answer: O.111 = D.73

b) D.511

c) D.23

If your answers were correct, continue on the next page. If not, ask your instructor for assistance.

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CONVERTING FROM OCTAL TO DECIMAL USING JOB AID 2A

Earlier you learned how to convert from decimal to octal using Job Aid 2A. To use the chart for converting from octal to decimal, follow the three steps below. Follow along with Job Aid 2A.

Example O.375 = D. _____

(1)	In the far left column, find the number that includes the first two (or three) characters of the octal number you are converting.	0370
(2)	In the top horizontal column, find the rightmost character of the octal number you are converting.	5
(3)	Find the decimal number at which the numbers from steps 1 and 2 meet. (Drop the first digit if it is 0.)	253

Answer: O.375 = D.253

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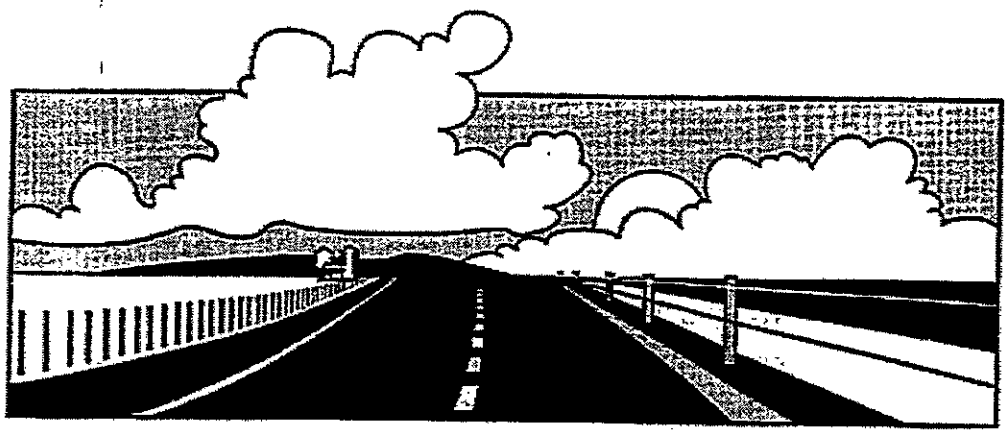

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JOB AID 2A - PRACTICE

Use Job Aid 2A to convert the octal numbers below.

a) O.577 = D. _____

b) O.200 = D. _____

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JOB AID 2A - PRACTICE ANSWERS

a) D.383

b) D.128

If your answers were correct, continue on the next page. If not, ask your instructor for assistance.

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JOB AID 6A, 6B

Job Aid 6A and 6B contain directions for converting octal to decimal and decimal to octal, for numbers higher than D.767 or O.1377. Review the conversion steps on Job Aid 6A and 6B now.

Practice

Using your job aids, work the following conversions.

a) O.2570 = D. _____

b) D.9706 = O. _____

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JOB AID 6A, 6B, continued

Practice Answers:

a) D.1400

b) O.22752

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CONVERTING FROM HEXADECIMAL TO DECIMAL

To find the decimal equivalent of a hexadecimal number, follow the three steps below. Remember the key words: weight, multiply, add.

Example X.425 = D. _____

(1) Write the weight of each hexadecimal column, right to left, until you have enough columns for your hexadecimal number.

Weight	256	16	1
Hex No.	4	2	5

Weight	256	16	1
Hex No.	4	2	5

(2) Multiply the weights in each column by the hexadecimal number in that column.

(3) Add the products of step 2.

5 x 1 = 5
2 x 16 = 32
4 x 256 = 1024
1061

Answer: X.425 = D.1061

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FROM HEXADECIMAL TO DECIMAL, continued

Here is another example.

Example X.1527 = D. _____

(1) Weight.

Weight	4096	256	16	1
Hex No.	5	6	0	1

(2) Multiply.

7 x 1 =	7
2 x 16 =	32
5 x 256 =	1280
1 x 4096 =	4096

(3) Add. 5415

Answer: X.1527 = D.5415

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FROM HEXADECIMAL TO DECIMAL - PRACTICE

Form the decimal equivalents for the hexadecimal numbers below.

a) X.125 = D. _____

b) X.334 = D. _____

c) X.1507 = D. _____

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FROM HEXADECIMAL TO DECIMAL - PRACTICE ANSWERS

a) D.293

(1) Weight.

Weight	256	16	1
Hex No.	1	2	5

(2) Multiply.

1 x 5 = 5
2 x 16 = 32
1 x 256 = 256

(3) Add. 293

b) D.820

c) D.5383

If your answers were correct, go on to page 69. If not, continue on to the next page.

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FROM HEXADECIMAL TO DECIMAL, continued

Steps

As you study this example, remember that the three steps are to weight each digit in the hexadecimal number, multiply each digit by the weight in its column, and add the products of your multiplication problems.

Example

X.423 = D. _____

(1) Weight.

Weight	256	16	1
Hex No.	4	2	3

(2) Multiply.

3 x 1 = 3
2 x 16 = 32
4 x 256 = 1024

(3) Add.

1059

Answer: X.423 = D.1059

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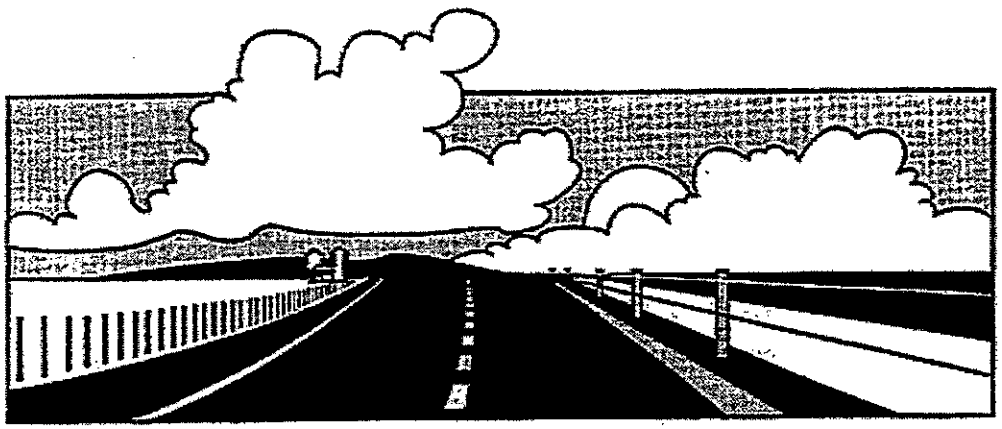

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FROM HEXADECIMAL TO DECIMAL - PRACTICE

Find the decimal equivalents for the hexadecimal numbers below.

a) X.231 = D. _____

b) X.3101 = D. _____

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FROM HEXADECIMAL TO DECIMAL - PRACTICE ANSWERS

a) D.561

(1) Weight.

Weight	256	16	1
Hex No.	2	3	1

(2) Multiply.

1 x 1 = 1
3 x 16 = 48
2 x 256 = 512

(3) Add. 561

Answer: X.231 = D.561

b) D.12545

If you are still having trouble with these conversions, see your instructor for assistance.

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FROM HEXADECIMAL TO DECIMAL, continued

When you converted hexadecimal numbers including only the digits 0 through 9, you needed only three steps: weight, multiply, and add. You did not need to convert the digits to decimal values because decimal and hexadecimal have the same values through the number 9. To convert hexadecimal numbers containing letters (A through F), however, you must convert all letters to decimal values before you can multiply. Notice in the example below that a new step is added: Convert.

Example X.7AF = D. _____

(1) Weight.	Weight	256	16	1
	Hex No.	7	A	F
(2) Convert.	Weight	256	16	1
(See Job Aid 1.)	Hex No.	7	A	F
	Dec. Val.	7	10	15

(3) Multiply. (Use decimal values.)
15 x 1 = 15
10 x 16 = 160
7 x 256 = 1792

(4) Add. 1967

Answer: X.7AF = D.1967

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FROM HEXADECIMAL TO DECIMAL, continued

Here is an example using a 4-column hexadecimal number. Remember the key words: weight, convert, multiply, add.

Example X.B2DA = D. _____

(1)	Weight.	Weight	4096	256	16	1
		Hex No.	B	2	D	A
(2)	Convert.	Weight	4096	256	16	1
	(See Job	Hex No.	B	2	D	A
	Aid 1.)	Dec. Val.	11	2	13	10

(3)	Multiply.	10 x 1 = 10
		13 x 16 = 208
		2 x 256 = 512
		11 x 4096 = 45056
(4)	Add.	45786

Answer: X.B2DA = D.45786

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FROM HEXADECIMAL TO DECIMAL - PRACTICE

Find the decimal equivalents for the hexadecimal numbers below.

a) X.5E = D. _____

b) X.C1D = D. _____

c) X.A7F2 = D. _____

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FROM HEXADECIMAL TO DECIMAL - PRACTICE ANSWERS

a) D.94

(1) Weight.

Weight	16	1
Hex No.	5	E

(2) Convert.

Weight	16	1
Hex No.	5	E
Dec. Val.	5	14

(3) Multiply.

14 x 1 = 14
5 x 16 = 80

(4) Add. 94

Answer: X.5E = D.94

b) D.3101

c) D.42994

If your answers were correct, go on to page 77. If not, ask your instructor for assistance on anything you did not understand.

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FROM HEXADECIMAL TO DECIMAL, continued

As you study the example below, remember the key words: weight, convert, multiply, add.

Example X.BED = D. _____

(1) Weight.

Weight	256	16	1
Hex No.	B	E	D

(2) Convert.

Weight	256	16	1
Hex No.	B	E	D
Dec. Val.	11	14	13

(3) Multiply.

13 x 1 = 13
14 x 16 = 224
11 x 256 = 2816

(4) Add. 3053

Answer: X.BED = D.3053

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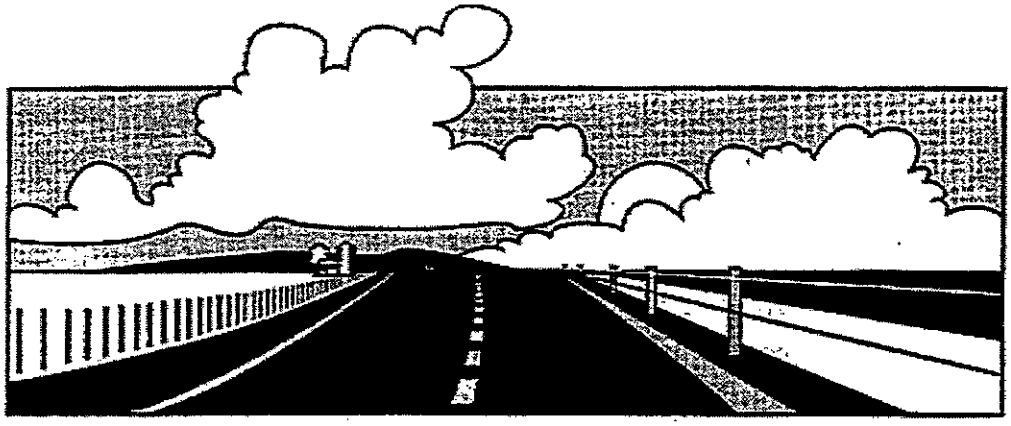

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FROM HEXADECIMAL TO DECIMAL - PRACTICE

Find the decimal equivalents for the hexadecimal numbers below.

a) X.FB1 = D. _____

b) X.1BAD = D. _____

c) X.214 = D. _____

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FROM HEXADECIMAL TO DECIMAL - PRACTICE ANSWERS

a) D.4017

(1) Weight.

Weight	256	16	1
Hex No.	F	B	1

(2) Convert.

Weight	256	16	1
Hex No.	F	B	1
Dec. Val.	15	11	1

(3) Multiply.

1 x 1 = 1
11 x 16 = 176
15 x 256 = 3840

(4) Add.

4017

Answer: X.FB1 = D.4017

b) D.7085

c) D.532

JOB AIDS 3, 4A, 4B

Earlier, you used Job Aids 3, 4A and 4B to convert from decimal to hexadecimal. To convert from hexadecimal to decimal, follow the three steps below. We will use X.228 for our example. Follow along on Job Aid 3.

Example X.228 = D. _____

(1) In the far left column, find the number that includes the first two (or three) characters of the hexadecimal number you are converting. — 0220

(2) In the top horizontal column, find the rightmost character of the hexadecimal number you are converting. — 8

(3) Find the decimal number at which the Numbers from step 1 and step 2 Meet. — 552

Answer: X.228 = D.552

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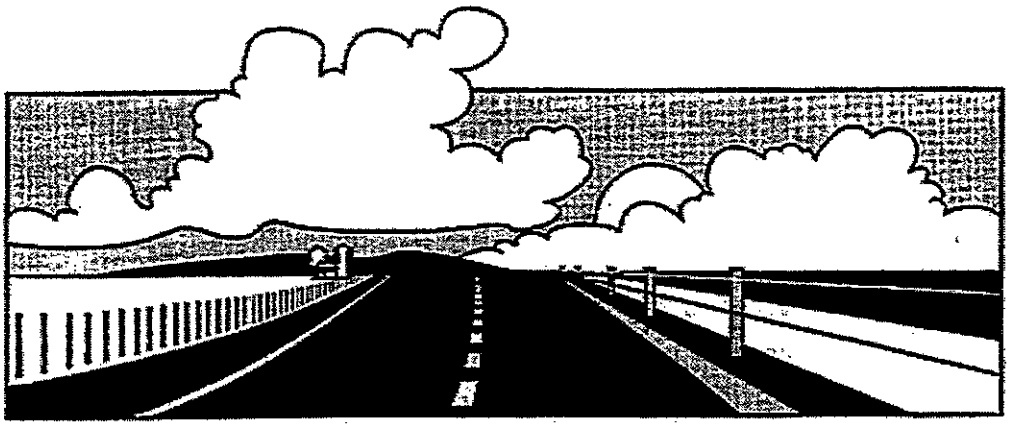

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JOB AIDS 3, 4A, 4B - PRACTICE

Job Aid 4A and Job Aid 4B contain directions for converting hexadecimal to decimal and vice versa. Study the examples and then use Job Aids 3, 4A and 4B to answer the questions below.

a) X.12A = D. _____

b) X.B1 = D. _____

c) X.9C1 = D. _____

d) X.FACE = D. _____

e) X.CE2 = D. _____

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JOB AIDS 3, 4A, 4B - PRACTICE ANSWERS

a) D.298

b) D.177

c) D.2497

d) D.64206

e) D.3298

If your answers were correct, go on to the next page. If not, ask your instructor for assistance.

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OPTIONAL DECIMAL TO HEXADECIMAL AND HEXADECIMAL TO DECIMAL - PRACTICE

If you wish to have some extra practice, work the conversion problems below. You may use any of your job aids.

a) D.94 = X. _____

b) X.115 = D. _____

c) X.324 = D. _____

d) D.127 = X. _____

e) X.B2D = D. _____

f) D.358 = X. _____

g) D.2867 = X. _____

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OPTIONAL DECIMAL TO HEXADECIMAL AND HEXADECIMAL TO DECIMAL - PRACTICE ANSWERS

a) X.5E

b) D.277

c) D.804

d) X.7F

e) D.2861

f) X.166

g) X.B33

If your answers were correct, go on to the next page. If not, ask your instructor for assistance on anything you did not understand.

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TO BINARY

CONVERTING FROM OCTAL TO BINARY

To convert from octal to binary, the 3 digits in each binary segment are weighted 4, 2, and 1 from left to right. The key steps are: write weights, record 1's, record 0's, condense. Follow the four steps in the example below.

Example O.4271 = B. _____

(1) Write weights under each digit of the octal number.	4 421	2 421	7 421	1 421
(2) Record 1's under all weights in each 3-bit group that total the octal value above.	1	1 (4+2+1=7)	111	1
(3) Record 0's under the remaining 3-bit weights.	100	010	111	001
(4) Condense the 3-bit groups into one binary number.	100010111001			

Answer: O.4271 = B.100010111001

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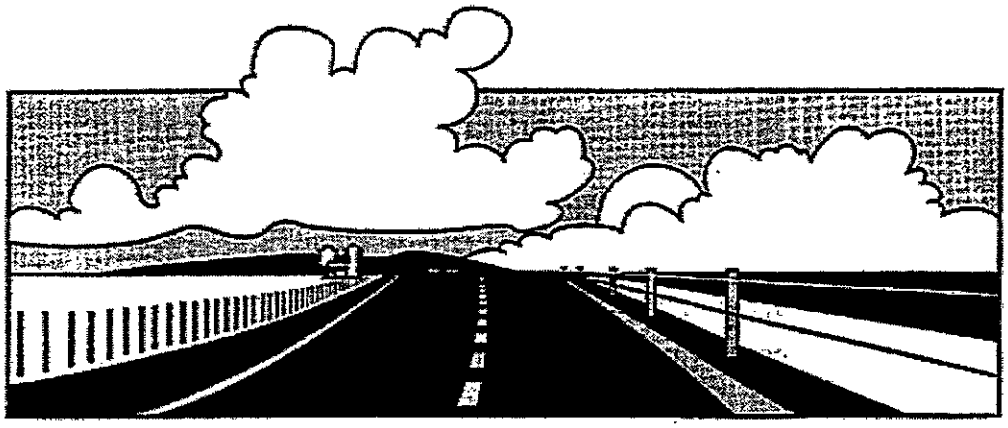

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FROM OCTAL TO BINARY - PRACTICE

Find the binary equivalents for the octal numbers below:

a) O.561 = B. _____

b) O.720 = B. _____

c) O.123 = B. _____

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FROM OCTAL TO BINARY - PRACTICE ANSWERS

a) B.101110001

(1) Write weights.	5 421	6 421	1 421
(2) Record 1's.	1 1	11	1
(3) Record 0's.	101	110	001
(4) Condense.	101110001		

Answer: O.561 = B.101110001

b) B.111010000

c) B.001010011 or B.1010011

If your answers were correct, go on to page 91. If not, continue on the next page.

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CONVERTING FROM OCTAL TO BINARY, continued

As you study the example below, remember the key steps for converting octal to binary: write weights, record 1's, record 0's, condense.

Example O.12557 = B. _____

(1) Write weights.	1 421	2 421	5 421	5 421	7 421
(2) Record 1's.	1	1	1 1	1 1	111
(3) Record 0's.	001	010	101	101	111
(4) Condense.	001010101101111				

Answer: O.12557 = B.001010101101111 or B.1010101101111

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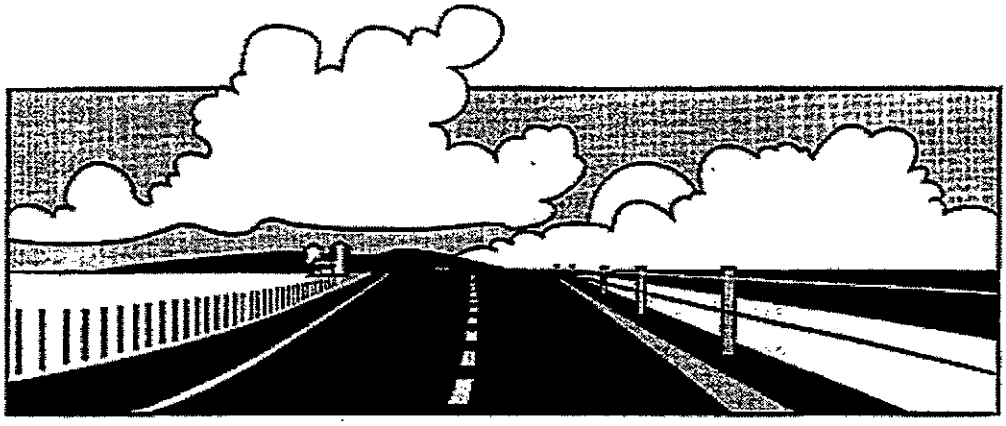

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FROM OCTAL TO BINARY - PRACTICE

By this time you may be able to do much of this converting without writing down all the steps. Find the binary equivalents for the octal numbers below, using any shortcuts you can.

a) O.17171 B. _____

b) O.777770 B. _____

c) O.127521 B. _____

d) O.3210 B. _____

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FROM OCTAL TO BINARY - PRACTICE ANSWERS

a) B.001111001111001 or B.1111001111001

(1) Write weights.	1 421	7 421	1 421	7 421	1 421
(2) Record 1's.	1	111	1	111	1
(3) Record 0's.	001	111	001	111	001
(4) Condense.	001111001111001				

Answer: O.17171 = B.001111001111001

b) B.1111111111111111000

c) B.0010101111010100001 or
B.1010111101010001

d) B.011010001000 or B.11010001000

If your answers were correct, continue on to the next page. If not, ask your instructor for assistance.

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CONVERTING FROM HEXADECIMAL TO BINARY

Conversion — To convert hexadecimal to binary, convert each hexadecimal character to its 4-digit (4-bit) binary equivalent.

Steps — Follow the steps below.

Example — X.8E5 = B. _____

(1) Write the 4-bit binary weights under each digit of the hexadecimal number.

8	E	5
8421	8421	8421

(2) Record 1's under all weights in each 4-bit group that total the hexadecimal value above. (Convert hexadecimal letters to decimal.)

1	111	1 1
(8+4+2=14)		(4+1=5)

(3) Record 0's under the remaining 4-bit weights.

1000	1110	0101

(4) Condense the 4-bit groups into one binary number.

100011100101

Answer: X.8E5 = B.100011100101

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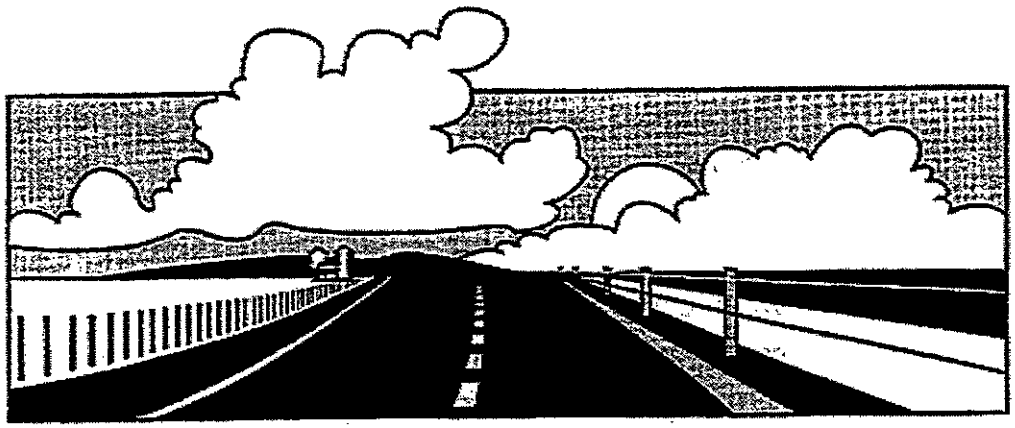

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FROM HEXADECIMAL TO BINARY - PRACTICE

Find the binary equivalents for the hexadecimal numbers below.

a) X.35 = B. _____

b) X.317A = B. _____

c) X.8B2F = B. _____

d) X.70A = B. _____

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FROM HEXADECIMAL TO BINARY - PRACTICE ANSWERS

a) B.00110101 or B.110101*

(1) Write weights. 3 5
8421 8421

(2) Record 1's. 11 1 1

(3) Record 0's. 0011 0101

(4) Condense. 00110101

Answer: X.35 = B.00110101 or B.110101

b) B.0011000101111010 or B.11000101111010

c) B.1000101100101111

d) B.011100001010 or B.11100001010

If your answers were correct, go on to page 99. If not, continue on to the next page.

* The binary value is the same with or without the beginning 0's.

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FROM HEXADECIMAL TO BINARY, continued

Here is another example. Remember the key words: write weights, record 1's, record 0's, condense.

Example X.5D24 = B. _____

(1)	Write weights.	5	D	2	4
		8421	8421	8421	8421
(2)	Record 1's. (Convert hexadecimal letters to decimal.)	1 1	11 1 (4+1=5)	1	1 (8+4+1=13)
(3)	Record 0's.	0101	1101	0010	0100
(4)	Condense.	01011101001001 00			

Answer: X.5D24 = B.01011101001001 00 or B.101110100100100

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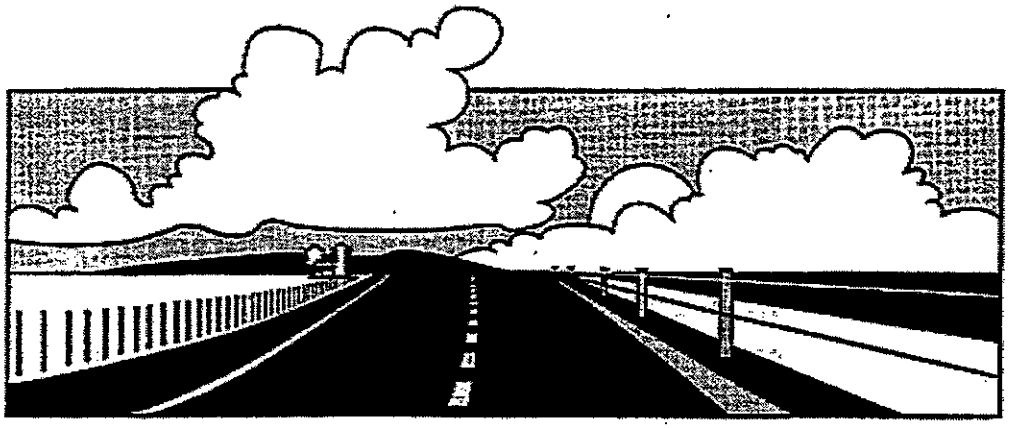

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FROM HEXADECIMAL TO BINARY - PRACTICE

Find the binary equivalents for the hexadecimal numbers below.

a) X.98CD = B. _____

b) X.14C = B. _____

c) X.2D = B. _____

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FROM HEXADECIMAL TO BINARY - PRACTICE ANSWERS

a) B.1001100011001101

(1) Write weights. 9 8 C D

(2) Record 1's. 1 1 1 11 11 1

(3) Record 0's. 1001 1000 1100 1101

(4) Condense. 1001100011001101

Answer: X.98CD = B.1001100011001101

b) B.000101001100 or B.101001100

c) B.00101101 or B.101101

If your answers were correct, go on to the next page. If not, see your instructor for assistance.

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FROM BINARY

CONVERTING FROM BINARY TO OCTAL

Steps

To convert a binary number to octal, you replace each 3-digit segment of the binary number (starting at the right) with one octal character. The three digits in each binary segment are weighted 4, 2, and 1 from left to right. Follow the three steps in the example below.

Example

B.1101010 = O. _____

(1) Separate the binary number into groups of three digits, from right to left. Add 0's to complete the group, if necessary.	001	101	010
	added 0's		
(2) Write the weight above each digit in each 3-digit (3-bit) group. Use weights of 4, 2, and 1.	421	421	421
	001	101	010
(3) Add the values of the weights above the 1's in each group.	1	5	2
		(4+1=5)	

Answer: B.1101010 = O.152

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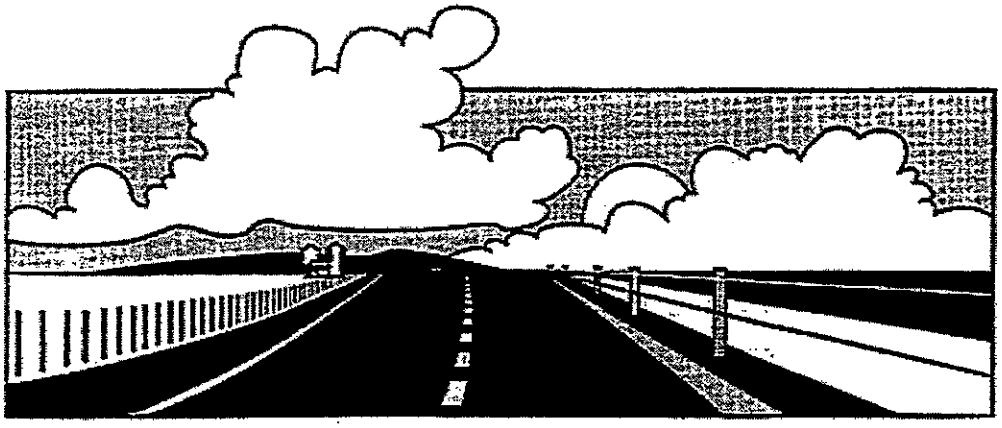

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FROM BINARY TO OCTAL - PRACTICE

Find the octal equivalents for the binary numbers below.

a) B.1100001 = O. _____

b) B.1011100 = O. _____

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FROM BINARY TO OCTAL - PRACTICE ANSWERS

a) O.141

(1) Separate.	001	100	001
	added 0's		
(2) Write weights.	421	421	421
(3) Add.	1	4	1

Answer: B.1100001 = O.141

b) O.134

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FROM BINARY TO OCTAL, continued

Here is a faster way to record information in binary-to-octal conversions.

Example B.01110 = O. _____

(1) Separate into 3's. Add 0's, if necessary.	001	110
	added 0	
(2) Weights.	421	421
(3) Add weights.	1	6

Answer: B.01110 = O.16

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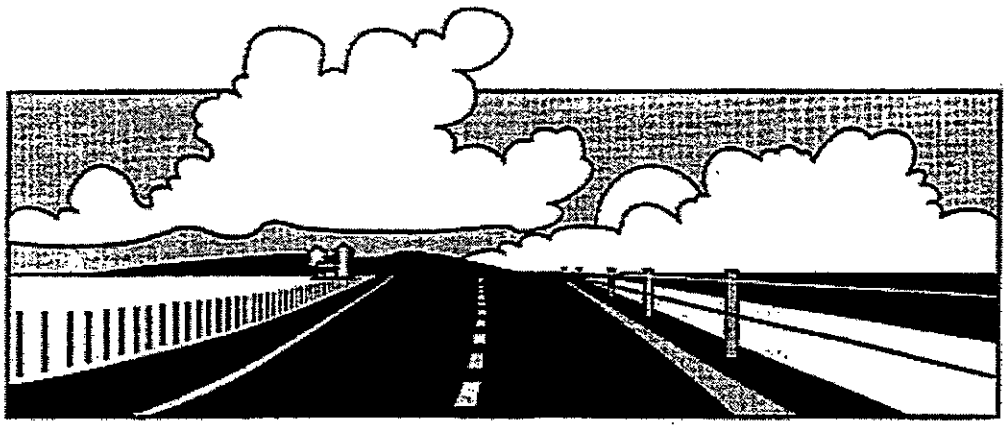

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FROM BINARY TO OCTAL - PRACTICE

Find the octal equivalents for the binary numbers below.

a) B.1100101 = O. _____

b) B.101110111 = O. _____

c) B.01101111011 = O. _____

d) B.111111111 = O. _____

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FROM BINARY TO OCTAL - PRACTICE ANSWERS

a) O.145

(1) Separate.	001	100	101
	added 0's		
(2) Weight.	421	421	421
(3) Add.	1	4	5

Answer: B.1100101 = O.145

b) O.567

c) O.1573

d) O.777

If your answers were correct, continue on to the next page. If not, ask your instructor for assistance.

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CONVERTING FROM BINARY TO HEXADECIMAL

Overview — The hexadecimal system is a shorthand method for expressing binary values. Converting binary to hexadecimal is just the opposite of converting hexadecimal to binary. A single hexadecimal character replaces a 4-digit binary number.

Steps — Follow the three steps below.

Example — B.111011001 = X._____

(1)	Separate the binary number into groups of four digits, from right to left. Add 0's to the left of the number, if necessary, to complete the group, if necessary.	0001 added 0's	1101	1001
(2)	Write the weight above each digit in each 4-bit group.	8421	8421	8421
(3)	Add the values of the binary weights above the 1's in each group. Below each group, record the hexadecimal equivalent of the sum.	1	D(D.13) (8+4+1=13)	9 (8+1=9)

Answer: B.111011001 = X.1D9

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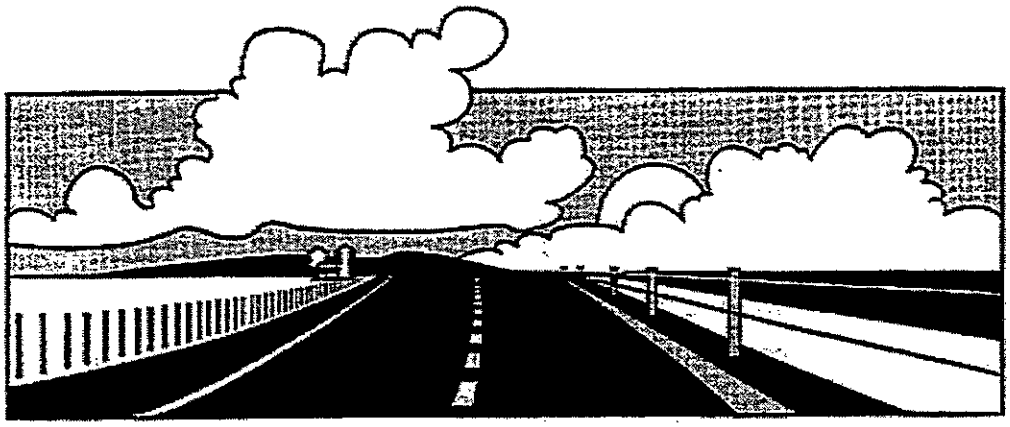

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FROM BINARY TO HEXADECIMAL - PRACTICE

Find the hexadecimal equivalents for the binary numbers below.

a) B.1111010101 = X. _____

b) B.101101111 = X. _____

c) B.1100110011 = X. _____

d) B.1110101 = X. _____

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BINARY TO HEXADECIMAL - PRACTICE ANSWERS

a) X.3D5

(1)	Separate.	0001 added 0's	1101	1001
(2)	Write weights.	8421	8421	8421
(3)	Add 1 and record sum. (Convert).	3	D(D.13) (8+4+1=13)	5 (4+1=5)

Answer: B.1111010101 = X.3D5

b) X.16F

c) X.333

d) X.75

If your answers were correct, go on to page 115. If not, continue on to the next page.

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BINARY TO HEXADECIMAL, continued

Here is an example using four columns. Remember the key words: separate, add 0's, write weights, add, record sums.

Example B.1010111000010 = X. _____

(1)	Separate and add 0's if necessary.	0001 added 0's	0101	1100	0010
(2)	Write weights.	8421	8421	8421	8421
(3)	Add and record sums.	1	5 (4+1=5)	C(D.12) (8+4=12)	2

Answer: B.1010111000010 = X.15C2

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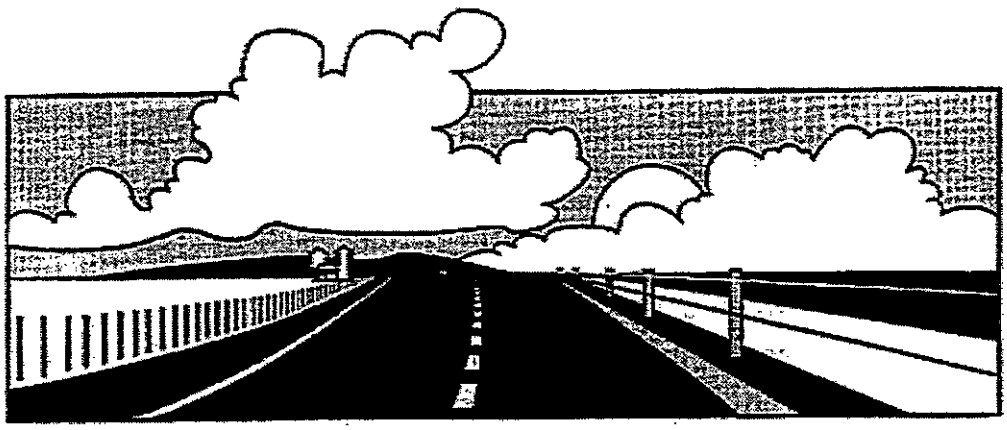

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FIND BINARY TO HEXADECIMAL - PRACTICE

Find the hexadecimal equivalents for the binary numbers below.

a) B.111011011 = X. _____

b) B.101111100111 = X. _____

c) B.10101100111 = X. _____

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FROM BINARY TO HEXADECIMAL - PRACTICE ANSWERS

a) X.1DB

(1)	Separate.	0001 added 0's	1101	1011
(2)	Write weights.	8421	8421	8421
(3)	Add and record sums.	1 (1=1)	D(D.13) (8+4+1=13)	B(D.11) (8+2+1=11)

Answer: B.111011011 = X.1DB

b) X.BE7

c) X.567

If your answers were correct, continue on to the next page. If not, see your instructor for assistance.

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CONVERTING FROM OCTAL TO HEXADECIMAL

Conversion

You will recall that converting octal to binary and binary to octal uses the same method as hexadecimal to binary and vice versa, except that the binary number is separated into groups of three instead of groups of four. These conversions use only the binary weights of 4, 2, and 1.

To convert from octal to hexadecimal, you must convert in two stages, as follows: stage 1: octal to binary, stage 2: binary to hexadecimal.

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FROM OCTAL TO HEXADECIMAL, continued

Example

You start with the octal number, convert it to binary, regroup into groups of four, and convert to hexadecimal. Here's an example.

O.12374 = X. _____

(1)	Write weights.	1 421	2 421	3 421	7 421	4 421
(2)	Record 1's.	1	1	11	111	1
(3)	Record 0's.	001	010	011	111	100
(4)	Regroup. (Groups of four.) added 0	0001	0100	1111	1100	
(1)	Write weights.	8421	8421	8421	8421	
(5)	Add and record sums.	1	4	F(D.15)	C(D.12)	

Answer: 0.12374 = X.14FC

Here is a simplified way to write the problem.

Octal number	1	2	3	7	4
Binary number	0001	010	011	111	100
Regroup	0001	0100	1111	1100	
Hexadecimal no.	1	4	F	C	

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FIND OCTAL TO HEXADECIMAL - PRACTICE

Find the hexadecimal equivalents for the octal numbers below.

a) O.46773 = X. _____

b) O.5714 = X. _____

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FROM OCTAL TO HEXADECIMAL - PRACTICE ANSWERS

a) X.4DFB

b) X.BCC

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FROM OCTAL TO HEXADECIMAL, continued

As you follow the example below, notice that only three weights (4, 2, and 1) are used in converting octal to binary. When you regroup the binary number into groups of four to find the hexadecimal equivalent, you use four weights (8, 4, 2, and 1).

Example O.125 = X. _____

(1) Write weights.	1 421	2 421	5 421
(2) Record 1's.	1	1	1 1
(3) Record 0's.	001	010	101
(4) Regroup.	0000	0101	0101
(1) Write weights.	8421	8421	8421
(5) Add and record sums. (Drop the beginning 0.)	0	5	5

Answer: B.1100101 = O.145

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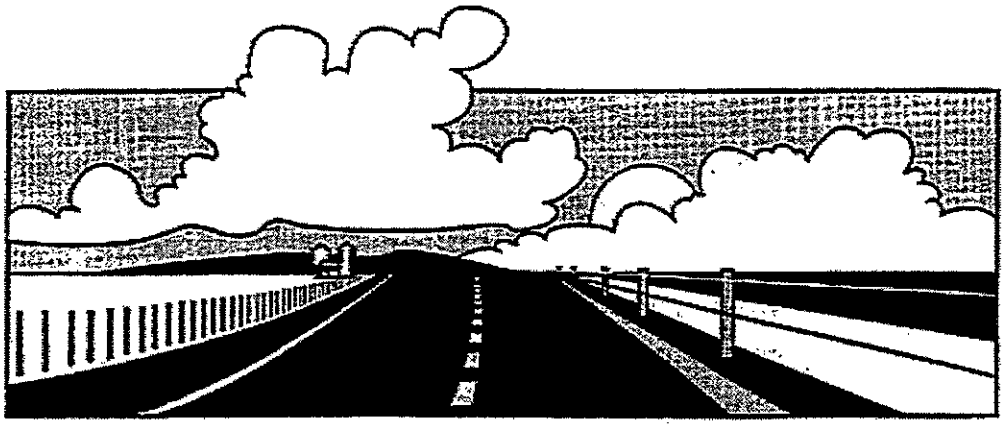

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FROM OCTAL TO HEXADECIMAL - PRACTICE

Find the hexadecimal equivalents for the octal number below.

a) O.217 = X. _____

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FROM OCTAL TO HEXADECIMAL - PRACTICE ANSWERS

a) X.8F

(1) Write weights.	2 421	1 421	7 421
(2) Record 1's.	1	1	111
(3) Record 0's.	010	001	111
(4) Regroup.	0000	1000	1111
(1) Write weights.	8421	8421	8421
(5) Add and record sums. (Drop the beginning 0.)	0	8	F(D.15)

Answer: O.217 = X.8F

If your answer was correct, continue on to the next page. If not, see your instructor for assistance.

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CONVERTING FROM HEXADECIMAL TO OCTAL

To convert hexadecimal to octal, you convert in two stages: hexadecimal to binary and then binary to octal. Follow the steps below.

Example X.5A7 = O. _____

(1) Write weights.	5	A(D.10)	7	
(2) Record 1's.	1 1	1 1	111	
(3) Record 0's.	0101	1010	0111	
(4) Regroup binary digits to groups of three, from right to left. Add 0's if nec.	010	110	100	111
(1) (Repeated.) Write weights.	421 010 2	421 110 6	421 100 4	421 111 7
(5) Add and record sums.	(4+2=6)		(4+2+1=7)	

Answer: X.5A7 = O.2647

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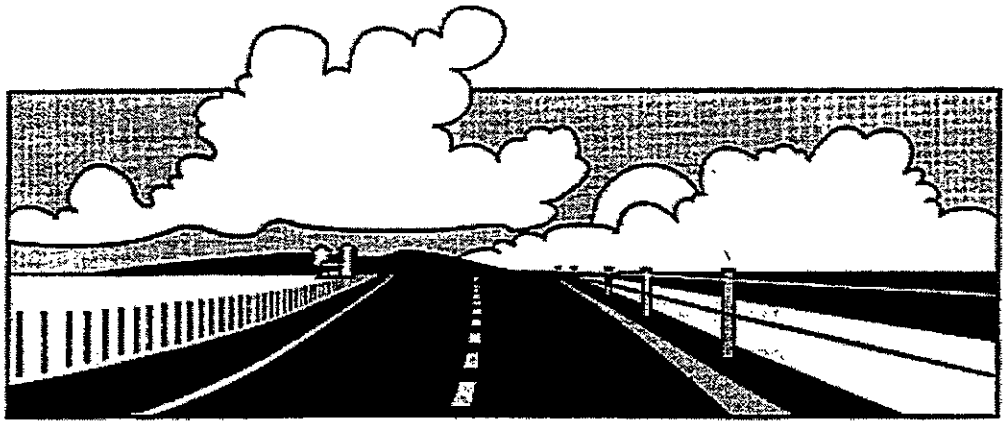

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FROM HEXADECIMAL TO OCTAL - PRACTICE

By this time you are probably able to perform many of the converting procedures without writing down each step in detail. Solve the problems below, using as many shortcuts as you can.

a) X.8B9 = O. _____

b) X.3792 = O. _____

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FROM HEXADECIMAL TO OCTAL - PRACTICE ANSWERS

a) O.4271

(1)	Write weights.	8 8421		B 8421 (X.B=D.11)	9 8421
(2)	Record 1's.	1		1 11	1 1
(3)	Record 0's.	1000		1011	1001
(4)	Regroup.	100	010	111	001
(1)	Write weights.	421	421	421	421
(5)	Add and Record sums.	4	2	7	1

Answer: X.8B9 = O.4271

b) O.33622

If your answers were correct, go on to page 131. If not, continue on the next page.

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FROM HEXADECIMAL TO OCTAL, continued

Look over the example below. Remember that the two stages in converting hexadecimal to octal are: hexadecimal to binary and then binary to octal.

Example X.FED = O. _____

(1)	Write weights.	F(D.15) 8421		E(D.14) 8421	D(D.13) 8421
(2)	Record 1's.	1111		111	11 1
(3)	Record 0's.	1111		1110	1101
(4)	Regroup into three's.	111	111	101	101
(1)	Write weights.	421	421	421	421
(5)	Add and record sums.	7	7	5	5

Answer: X.FED = O.7755

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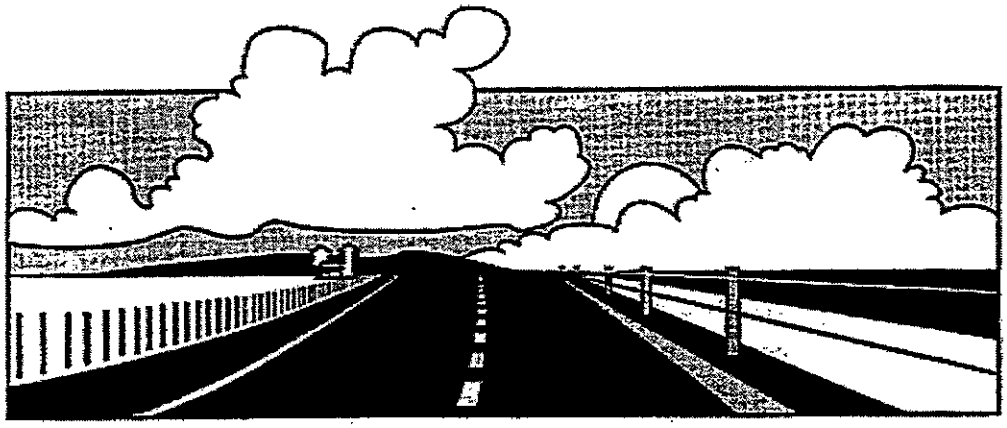

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FROM HEXADECIMAL TO OCTAL - PRACTICE

Find the octal equivalents for the hexadecimal numbers below.

a) X.1A = O. _____

b) X.569 = O. _____

c) X.B12 = O. _____

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FROM HEXADECIMAL TO OCTAL - PRACTICE ANSWERS

a) O.32

(1)	Write weights.	1 8421		A 8421
				(X.A=D.10)
(2)	Record 1's.	1		1 1
(3)	Record 0's.	0001		1010
(4)	Regroup. (Groups of three.)	000	011	010
		added 0		
(1)	Write weights.	421	421	421
(5)	Add and record sums.	0	3	2

Answer: X.1A = O.32

b) O.2551

c) O.5422

If your answers were correct, continue on the next page. If not, see your instructor for assistance.

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REVIEW

To review all the conversion procedures you have learned in this module, work the following pages. You may use your job aids.

a) D.567 = B. _____

b) D.447 = B. _____

c) D.5263 = O. _____

d) D.21 = O. _____

e) D.425 = X. _____

f) D.218 = X. _____

g) B.101011 = D. _____

h) B.0110110101 = D. _____

i) O.154 = D. _____

j) O.1234 = D. _____

k) X.7AF1 = D. _____

l) X.52E = D. _____

m) O.711 = B. _____

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REVIEW, continued

n) O.153 = B. _____

o) X.6B2 = B. _____

p) X.B15 = B. _____

q) B.10111 = O. _____

r) B.111 = O. _____

s) B.1011100111 = X. _____

t) B.1000111011 = X. _____

u) O.516 = X. _____

v) O.1631 = X. _____

w) X.BD57 = O. _____

x) X.5AF2 = O. _____

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REVIEW - ANSWERS

a) B.1000110111

b) B.110111111

c) O.12217

d) O.25

e) X.1A9

f) X.DA

g) D.43

h) D.437

i) D.108

j) D.668

k) D.31473

l) D.1326

m) B.111001001

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REVIEW - ANSWERS, continued

n) B.001101011 or B.1101011

o) B.011010110010 or B.11010110010

p) B.101100010101

q) O.27

r) O.7

s) X.2E7

t) X.23B

u) X.14E

v) X.399

w) O.136527

x) O.55362

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NUMBERING SYSTEMS CONVERSION CHART

On the last page of this module is a numbering systems conversion chart, Figure 1. This fold-out chart may assist you with the conversions covered in this module. You may wish to discuss this chart with your Instructor.

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CONCLUSION

This concludes Module 2. Before taking the test, you may review the material in the module. There is an index of subjects for Module 2 on the following page. Clear up any questions you may have with the Instructor. Return to the beginning of the module and review the objective. When you are ready, ask your Instructor for a copy of the test for Module 2. You may use your job aids during the test.

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SUBJECT INDEX - MODULE 2

Subject	Page
Binary to decimal	39
Binary to hexadecimal	107
Binary to octal	99
Decimal to binary	9
Decimal to hexadecimal	23
Decimal to octal	15
Hexadecimal to binary	91
Hexadecimal to decimal	61
Hexadecimal to octal	123
Introduction to the four numbering systems	3
Job 2A, 2B	19
Job Aid 1	4
Job Aid 3	35
Job Aid 4A, 4B	37
Job Aid 5	43
Job Aids 6A, 6B	59
Octal to binary	83
Octal to decimal	47
Converting to octal to decimal using Job Aid 2A	55
Octal to hexadecimal	115
Overview of numbering systems	4
Weighting	5

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Introduction to Digital Technologies for COT

US*WEST*
COMMUNICATIONS

Module 3
Electrostatic Discharge Prevention

January, 2000

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DOCUMENT RELEASE NUMBER	DOCUMENT STATUS	DATE	SOFTWARE FILE NAME
0.01	Revised original course material and updated test questions	01/11/00	Mod 3 manual.doc

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Table of Contents

ELECTROSTATIC DISCHARGE PREVENTION....1
PURPOSE AND PREVIEW....1
Purpose....1
Preview....1
OBJECTIVES....2
INTRODUCTION TO ELECTROSTATIC DISCHARGE....3
Zapped?....3
Circuit Pack....3
Video....3
WHAT IS ESD?....4
Definition....4
CAUSES OF ESD....5
ESD Occurrence....5
Factors....5
Everyday Tasks....5
SOURCES OF ESD....6
Sources....6
ESD Sensitivity....6
Device Sensitive....6
EFFECTS OF ESD....7
Noise Transients....7
Component Deterioration....7
Effect of Failures....7
REVIEW....9
Myths Versus. Reality....12
Prevention Procedures....13
Wrist Strap....13
Synthetic Materials....13
Static-free Storage....13
Work Surface....13
Prevention Procedures....14
REVIEW....16
HANDLING CIRCUIT PACKS....19
REPLACING CIRCUIT PACKS....20
WRIST STRAP TESTING....22
Testing....22

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FURTHER GUIDELINES 23
SHIPPING AND RECEIVING 24
Shipping 24
Receiving 24
REVIEW 25
CONCLUSION 28

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ELECTROSTATIC DISCHARGE PREVENTION

PURPOSE AND PREVIEW

Purpose

The purpose of the lesson is to enable you to identify the correct procedures for electrostatic discharge prevention. Electrostatic discharge can be very damaging in the Central Office environment. Learning the theory, causes and prevention procedures for electrostatic discharge will enable you to protect U S WEST assets.

Preview

Subjects included in this module are as follows:

- ☆ Introduction to electrostatic discharge
- ☆ What is ESD?
- ☆ Causes of ESD
- ☆ Sources of ESD
- ☆ Effects of ESD
- ☆ Myths of electrostatic discharge
- ☆ Prevention of ESD damage
- ☆ Handling circuit packs
- ☆ Replacing circuit packs
- ☆ Wrist strap procedures
- ☆ Shipping and receiving

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OBJECTIVES

At the conclusion of this module, the student will be able to correctly list the precautions necessary for handling semiconductor devices.

The student will be provided with a written test, comprised of multiple choice and matching term to definition type questions. During the test, the student may not refer to any reference material.

Evidence of satisfactory learning will be demonstrated by correctly completing 16 out of 21 questions on the test.

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INTRODUCTION TO ELECTROSTATIC DISCHARGE

Zapped?

Have you ever been "zapped" by a small burst of electricity? You may have noticed this at your home, especially in winter, as you reached for the doorknob after walking across your carpeted floor. This small zap is the result of what is called electrostatic discharge, or ESD.

Circuit Pack

ESD is now considered one of the major causes of defective circuit packs in all equipment associated with Central Office switching systems. For the purpose of this module, the term, circuit pack, refers to any electronic equipment plug-in card or "pack." These devices may also be called circuit boards, printed wiring boards, or circuit cards.

Estimates of ESD damaged circuit packs range as high as 50% of all packs sent in for repair. Circuit packs can be very expensive to replace, ranging up to thousands of dollars per unit. This module will help anyone who is responsible for static-sensitive electronic equipment know the proper way to handle, ship, receive, repair and control the possibility of ESD damage.

Video

You are now going to watch a short video, titled "Electrostatic Discharge." Let your instructor know that you are ready to watch the video. When you have finished watching it, continue on to the next page.

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WHAT IS ESD?

Electrostatic discharge is the sudden release of accumulated electrical charges on an object or a person, to another object or person having a different potential static charge or ground.

At lower levels of static charges, there may be no sensation to indicate that ESD has occurred, however, the energy charge may be sufficient to damage or destroy static-sensitive equipment.

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CAUSES OF ESD

ESD Occurrence

Static electricity occurs anytime two materials contact or are rubbed together and then separated. The amount of static charge depends on the types of material that have come in contact, the types of surfaces and environmental factors such as relative humidity.

Factors

Some factors which affect the charge level may not be apparent. These include the design of the product, the materials used in the product assembly, and chemicals and other materials used in the manufacturing process.

The static charge level or potential that can be generated is affected by factors such as relative humidity, airflow rate, floor materials, furniture, clothing and individuals.

Everyday Tasks

Static electricity may be generated by simple everyday tasks, such as:

▲ Walking across linoleum	5,000 volts
▲ Handling bubble plastic	20,000 volts
▲ Working at a bench	800 volts
▲ Handling foam containers	11,000 volts

The seemingly unimportant act of pulling plastic tape off of a dispenser can generate a static charge of 3,000 volts!

The potential for causing a discharge pulse with sufficient power to alter device parameters or cause catastrophic device failure is ever present in the telecommunications equipment environment.

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SOURCES OF ESD

Sources

Electrostatic charged sources commonly encountered in a switched network facility are as follows:

- Work surfaces
- Floors
- Chairs
- Personnel clothing
- Cleaning and test areas
- Part and assembly packaging materials (untreated)

ESD Sensitivity

To illustrate the various device or component sensitivity level, the minimum ranges that can cause ESD damage are given below.

Diodes	300 to 2500 volts
Bipolar	380 to 7000 volts
Eprom	100 volts
Resistors	300 to 3000 volts

Device Sensitive

Very often, ESD damage goes unnoticed because the threshold for human sensation ("shock") can range from 1500 to 3500 volts. At lower levels of static charge, there will be no indication that ESD has occurred, but the energy flow may be enough to damage or destroy static-sensitive components.

[redacted]

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EFFECTS OF ESD

Noise Transients

There is more to equipment sensitivity than just the damage done to electrical devices. [redacted]

Component Deterioration

If a component's [redacted] is altered, it may take on a slow deterioration process that will cause it to fail later.

Effect of Failures

Some typical failures that may occur are shown below.

Data terminal transmission	✘	Transmits wrong data
	✘	Loses all data
Main computer memory	✘	Parity errors
	✘	Complete program loss
Printers	✘	Overprint
	✘	Print garbled data
Disk and tape units	✘	Write incorrect data

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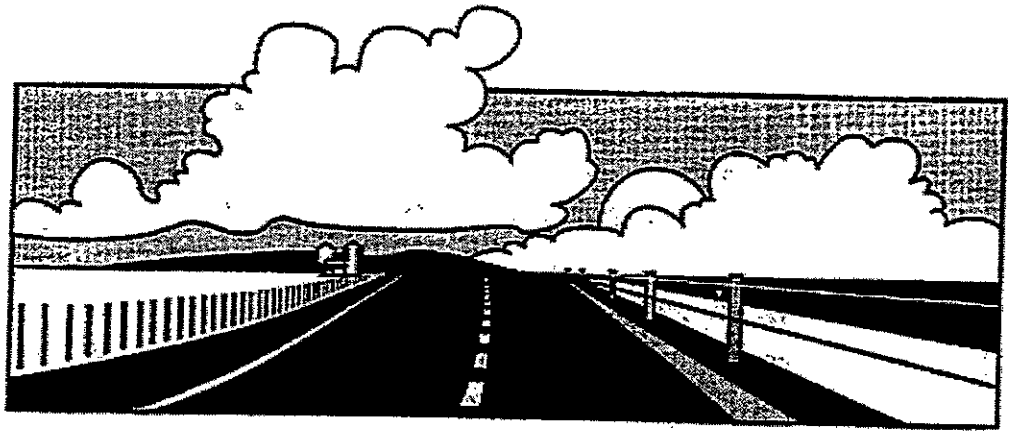

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REVIEW

Complete the review according to the directions provided. Answers are provided on the following page.

1) ESD _____ is considered one of the major causes of defective circuit packs in equipment associated with Central Office switching systems.

2) Static electricity occurs anytime two materials _____ or are _____ together and then separated.

Indicate whether the statement is true or false.

3) Working at a bench or pulling plastic tape off a dispenser can generate a static charge.
☒ True or ☐ False.

4) Sources of ESD include chairs and clothing.
☒ True or ☐ False._____

5) Static electricity can damage components when no shock is felt.
☒ True or ☐ False._____

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REVIEW - ANSWERS

1) **ESD** is considered one of the major causes of defective circuit packs in all equipment associated with Central Office switching systems.

2) Static electricity occurs anytime two materials **contact** or are **rubbed** together and then separated.

3) Working at a bench or pulling plastic tape off a dispenser can generate a static charge.
True

4) Sources of ESD include chairs and clothing.
True

5) Static electricity can damage components when no shock is felt.
True

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MYTHS OF ELECTROSTATIC DISCHARGE

There are some myths and misconceptions floating around about ESD.

Myths Versus. Reality

The following chart looks at some of these myths and what actually is the reality.

MYTH	REALITY
You can ground yourself by touching equipment frames.	Just by moving a foot causes a reduction in capacitance. Voltage increases and danger is present.
Components on printed wiring boards are not susceptible to static charge damage.	The printed wiring goes directly to the components. The probability of damage is greater.
Personnel must actually touch devices or circuit packs to damage them.	Just exposing a pack to an electrical field may induce damage.
Circuit packs that test okay after improper handling have not been damaged.	If a low level ESD has been applied, undetectable damage to components can worsen and result in premature failure of circuit boards.

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PREVENTION OF ESD DAMAGE

Prevention Procedures

There are some basic prevention procedures that apply when handling static-sensitive circuits. Let's look at them.

Wrist Strap

✔ Wear a static control wrist strap. The wrist strap cord should be grounded. Use of a grounded wrist strap is the single biggest contribution to an effective ESD program.

The bare part of your skin must be in contact with the strap, and the [illegible] grounding [illegible] onto a metal [illegible].

You should put on the grounded wrist strap on your wrist before [illegible] any work on circuit packs.

Synthetic Materials

✔ Synthetic [illegible] that are not anti-static should not be brought into the equipment area. The [illegible] area should be free of materials [illegible] styrofoam, plastics, food wrappers [illegible].

Static-free Storage

✔ Ground [illegible] all storage cabinets. Grounding the cabinets will help provide a static-free storage area.

Work Surface

✔ Use an [illegible] grounded table mat. The table mat, in conjunction with the use of a grounded wrist strap, will help provide a static-free work area surface for inspection and repair of circuit packs.

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PREVENTION OF ESD DAMAGE, continued

Prevention Procedures

✔ Post ESD warning signs, posters, and markers for each Central Office. ESD-sensitive work will be restricted to personnel who maintain the equipment. An example of a warning sign is shown below.

Warning Symbol for ESD

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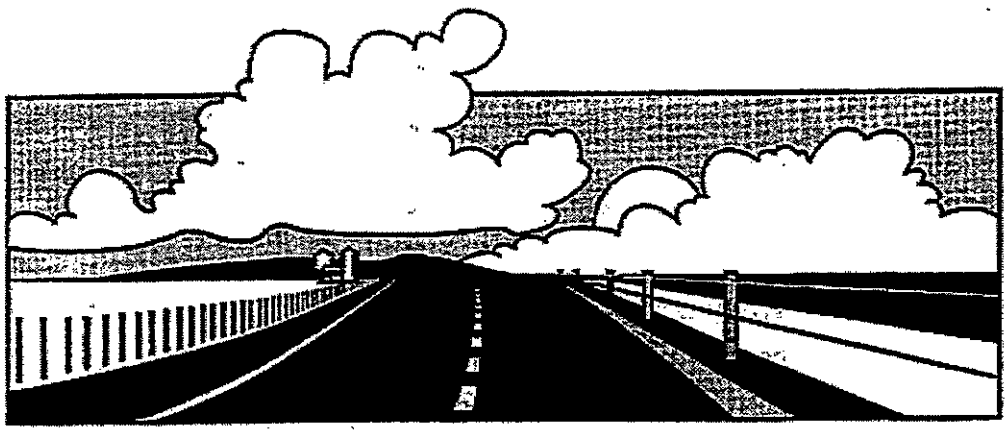

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REVIEW

1) List two ways to ground a static control wrist strap.
ground plug or metal frame

2) List two examples of synthetic materials that should not be brought into the equipment area.
Nylon jacket, Styrofoam

3) Storage cabinets should be grounded.

4) Personnel must actually touch devices or circuit packs to damage them.
☐ True or ☒ False.

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REVIEW - ANSWERS

1) List two ways to ground a static control wrist strap. **The cord can be plugged into a grounding jack or clipped onto a metal frame.**

2) List two examples of synthetic materials that should not be brought into the equipment area. **Any two: styrofoam, plastics, food wrappers.**

3) Storage cabinets should be **properly grounded**.

4) Personnel must actually touch devices or circuit packs to damage them. **False**

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HANDLING CIRCUIT PACKS

Guidelines

Let's now focus on the rules and guidelines for replacing circuit packs. First, let's look at some rules for handling circuit packs.

- [redacted] will ensure protection of the circuit pack at all times.

- [redacted] or a grounded [redacted] Laying circuit packs on desks, table tops, or floors may cause damaged device or component.

- [redacted] Damage may be induced to the components by scratching conductive paths or terminals.

- [redacted] Further damage may occur if defective packs are not handled properly. This will increase repair costs.

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REPLACING CIRCUIT PACKS

Now let's look at the guidelines for replacing circuit packs. We'll look at the process in a step-by-step manner.

Step 1 — The first step is obtain a replacement pack from storage. Observing the circuit pack, take action as follows:

Is the circuit pack stored in a static proof bag or carton?		
IF	Then	And
NO	Connect wrist strap to storage cabinet ground.	Provide static proof bag or container to transport pack.
YES	Use wrist straps when handling packs to ensure good ESD prevention habits.	Continue to step 2.

Step 2 — Carry the replacement circuit pack to the work location in the proper static proof container.

Step 3 — Go to the equipment bay that contains the faulty circuit pack. Put your wrist strap on and connect the wrist strap to the equipment bay ground.

Step 4 — Remove the defective circuit pack. Place the faulty pack on a grounded portable work mat.

CAUTION — Always handle circuit packs by the face plate or the top and bottom edges of the pack. To prevent further damage, never touch the components, conductive paths, or terminals.

Continued

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REPLACING CIRCUIT PACKS, continued

Step 5	Remove the replacement circuit pack from its static-proof container and place it in the equipment bay location that the faulty pack was removed from.
Step 6	Restore the equipment to on-line status.
Step 7	Place the defective pack in the static-proof container that was used to hold the replacement pack.
Caution	Defective packs should be treated with the same ESD handling procedures as new packs. This will prevent further damage that can increase repair cost.
Step 8	Disconnect the wrist strap from the equipment bay ground.

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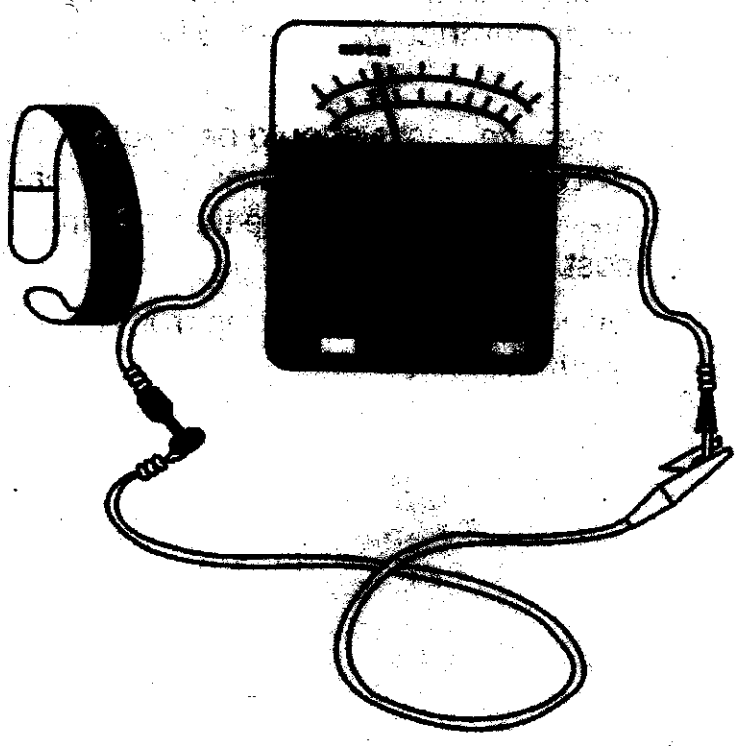
WRIST STRAP TESTING

Testing

Wrist straps should be tested at least once a week for effectiveness, using a wrist strap tester or a volt-ohm meter.



Meter Settings

To test the cord with a volt-ohm meter, set the meter to the 10 k ohm setting. [illegible] between the snap connector and the ground clip should measure greater than 500,000 ohms. On the meter scale, this is less than 1,100,000 ohms. The resulting reading will be approximately 500,000 ohms (500 k).

Note

Measurement of the wrist strap is to be taken from the snap connector to the ground clip. Do not measure from the wrist strap material.

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FURTHER GUIDELINES

ESD preventive procedures also cover the following:

- ❑ Trouble analysis and maintenance of Central Office equipment.
- ❑ Shipping and receiving.

A grounded wrist strap should be worn when performing the above jobs. This will ensure that the circuit packs and the equipment will be protected at all times.

For example, the wrist strap should be used when making wiring option changes on switch back plates, terminal strips, etc.

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SHIPPING AND RECEIVING

The following guidelines should be followed for shipping and receiving static-sensitive equipment.

Shipping

These points apply to shipping circuit packs:

- ➢ Ship the circuit packs in the appropriate vendor shipping cartons.
- ➢ Prepare for shipping at a static safe work area.
- ➢ Place defective packs in static-proof bags before placing them in a shipping carton.
- ➢ Use defective tags in lieu of defective tape.
- ➢ Use ESD warning labels to seal the shipping carton.

Receiving

These points apply to receiving circuit packs:

- ➢ When received, store circuit packs in their shipping cartons, in metal cabinets.
- ➢ Ground any open storage cabinet.
- ➢ The person receiving and storing circuit packs will wear their wrist strap.
- ➢ Use a static-free work area to unpack, inspect, or test circuit packs.

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REVIEW

1) Transport all circuit packs in ESD-safe packaging.

2) Why should you treat defective packs with the same handling procedures as new packs?
Reduce potential repair costs

3) You are replacing a circuit pack. Before doing anything at the equipment bay, what should you do?
Put on wrist-strap and connect to ground (frame or ground plug)

4) You have just replaced a defective circuit pack at the equipment bay. What do you do with the faulty pack?
Put in same packaging as new pak.

5) Always handle circuit packs by the front plate or the top and bottom edges of the pack.

6) Defective packs should be treated with the same ESD handling procedures as new packs.

7) When circuit packs are received, how should they be stored?
in their shipping carton in metal cabinets

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REVIEW - ANSWERS

1) Transport all circuit packs in **static-proof** packaging.

2) Why should you treat defective packs with the same handling procedures as new packs? **Further damage may occur if defective packs are not handled properly.**

3) You are replacing a circuit pack. Before doing anything at the equipment bay, what should you do? **Put your wrist strap on and connect it to the equipment bay ground.**

4) You have just replaced a defective circuit pack at the equipment bay. What do you do with the faulty pack? **Place the defective pack in the static-proof container that used to hold the replacement pack.**

5) Always handle circuit packs by the **face plate** or the top and bottom edges of the pack.

6) Defective packs should be treated with the **same** ESD handling procedures as new packs.

7) When circuit packs are received, how should they be stored? **In their shipping containers, in metal cabinets.**

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CONCLUSION

This concludes Module 3.

Before taking the test, you may review the material in the module.

Clear up any questions you may have with the Instructor.

Return to the beginning of the module and review the objective.

When you are ready, ask your Instructor for a copy of the Module 3 test.

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